

NOVEL EPITHELIAL TISSUE IMAGING AGENT

Cross-reference of Related Applications

[0001] This application is a continuation application of co-pending U.S. application Serial No. 09/005,167, filed 01/09/98, which is a continuation-in-part of U.S. application Serial No. 08/782,480, filed January 10, 1997, now U.S. Patent No. 6,045,774.

Technical Field

[0002] The present invention relates generally to the targeting of diagnostic compounds to specific cells and tissues. The invention is more particularly related to targeting molecules for use in delivering compounds to epithelial tissue. Such targeting molecules may be used in a variety of diagnostic procedures.

Background of the Invention

[0003] To improve the diagnosis of cancer and other disorders, some researchers have used the systemic administration of imaging agents (*e.g.*, proton relaxation agents as well as fluorescent chromophores) for contrast enhancement in techniques such as magnetic resonance imaging (MRI) and laser phototherapy. For example, tumor location using radiolabeled antibodies and handheld probes for intraoperative tumor detection has been attempted (Arnold et al., *Surgery* 112:624-631, 1992). Introduction of fluorescein conjugated antibodies for endoscopic tumor location ("photo-immunodiagnosis") in animals and in humans has also been attempted (Folli et al., *Cancer Res.* 54:2643-2450, 1994; Pelegrin et al., *Cancer* 67:2529-2535, 1994). In addition, fluorochrome-conjugated antibodies have been used to study antibody circulation in tumor microvasculature and biodistribution in tumors.

[0004] While such techniques show promise, their use has been limited by a lack of agents or conjugates that show specific localization to particular cell types. For example, localization to cell populations that are frequent sites of neoplastic development would aid in the diagnosis of incipient tumors. Further selectivity for

neoplastic cells or macroscopic tumors would greatly aid in their localization and excision.

[0005] The ability to target imaging compounds to epithelial cells would enhance a variety of diagnoses, since such cells give rise to a wide spectrum of tumors, as well as viral and bacterial infections. Targeting of imaging compounds to epithelial cells would ideally delineate normal tissue from neoplastic lesions and potentially identify other types of lesions such as infections. Refinement of cell type specificity to be selective for the abnormal cells would further aid in localizing and treating those cells. However, no techniques are currently available for such targeting of imaging agents.

[0006] Accordingly, there remains a need in the art for systems for delivering imaging agents to target cells, particularly epithelial cells and cells or tissues bounded by epithelial cells. The present invention fulfills these needs and further provides other related advantages.

Summary of the Invention

[0007] Briefly stated, the present invention provides targeting molecules for the specific delivery of imaging agents to epithelial cells and tissues. In several aspects, the present invention provides a targeting molecule linked to at least one imaging agent. In one such aspect, the targeting molecule comprises a polypeptide that (a) forms a closed covalent loop; and (b) contains at least three peptide domains having β -sheet character, each of the domains being separated by domains lacking β -sheet character; wherein the polypeptide is not a full length dimeric IgA. In specific embodiments, the polypeptide further contains one or more of the following additional domains: a fourth peptide domain having β -sheet character, separated from other domains having β -sheet character by a domain lacking β -sheet character; a linear N-terminal domain; and a C-terminal domain, which may comprise a linear peptide having β -sheet character and/or a covalently closed loop.

[0008] Within other such aspects, the targeting molecule comprises a sequence recited in any one of SEQ ID NO:1 - SEQ ID NO:8 and SEQ ID NO:13.

[0009] In a further related aspect, the present invention provides a targeting molecule capable of specifically binding to a basolateral factor associated with an

epithelial surface and causing the internalization of an imaging agent linked thereto, wherein the targeting molecule is not full length dimeric IgA.

[0010] Within another such aspect, the targeting molecule comprises a polypeptide that: (a) forms a closed covalent loop; and (b) contains at least three peptide domains having β -sheet character, each of the domains being separated by domains lacking β -sheet character; wherein the targeting molecule is linked to at least one imaging agent by a substrate for an intracellular or extracellular enzyme associated with an epithelial barrier, or by a side chain of an amino acid in an antibody combining site.

[0011] Within yet another such aspect, the targeting molecule comprises a polypeptide that: (a) forms a closed covalent loop; and (b) contains at least three peptide domains having β -sheet character, each of the domains being separated by domains lacking β -sheet character; wherein the imaging agent is not naturally associated with the targeting molecule, and wherein the imaging agent is not iodine.

[0012] Within another aspect, the present invention provides a pharmaceutical composition comprising a targeting molecule linked to at least one imaging agent as described above in combination with a pharmaceutically acceptable carrier.

[0013] In further aspects, methods are provided for diagnosing a disease in a patient, comprising (a) administering to a patient a pharmaceutical composition as described above; and (b) detecting the presence of imaging agent within the patient.

[0014] These and other aspects of the present invention will become apparent upon reference to the following detailed description and attached drawings. All references disclosed herein are hereby incorporated by reference in their entirety as if each was incorporated individually.

Brief Description of the Drawings

[0015] Figure 1 is a comparison of native J chain sequences reported for human (top line), mouse (second line), rabbit (third line), cow (fourth line), bull frog (fifth line) and earth worm (sixth line). For each non-human sequence, amino acid residues that are identical to those in the human sequence are indicated by a dash. Residues that differ from the human sequence are indicated using standard one letter abbreviations.

Detailed Description of the Invention

[0016] As noted above, the present invention is generally directed to targeting molecules (TMs) for use in the delivery of imaging agents to epithelial cells. Upon delivery to an epithelial cell, extracellular enzymes at the basolateral surface may release an imaging agent from a TM in, for example, a region of a lesion. An imaging agent may remain within the target cell or may undergo transepithelial transport via transcytosis. For example, the agent and TM may be transported across the basolateral surface and remain within the epithelial cell, or the agent may remain within the cell while the TM undergoes transepithelial transport. Alternatively, both the agent and TM may undergo transcytosis. For example, an agent linked to a TM may pass through an epithelial cell surface to access an adjacent cell, tissue or compartment (*e.g.*, lumen of the small intestine, bronchial airway, vaginal cavity).

[0017] Prior to setting forth the present invention in detail, definitions of certain terms used herein are provided.

[0018] Epithelial surface (or epithelial barrier): A surface lining the exterior of the body, an internal closed cavity of the body or body tubes that communicate with the exterior environment. Epithelial surfaces include the genitourinary, respiratory, alimentary, ocular conjunctiva, nasal, oral and pharyngeal cavities, as well as the ducts and secretory portions of glands and receptors of sensory organs. The term “epithelial surface” as used herein is synonymous with “epithelial barrier.” One side of an epithelial surface is free of adherence to cellular and extracellular components, other than coating substances and secretions. The other side of the surface is normally adjacent to the basement membrane and is exposed to interstitial fluids and components of the underlying tissues. Epithelial surfaces are typically formed from cells in close apposition to one another, the contact between plasma membranes of adjacent cells characterized by a tight junction (zonula occludens) which delimits the outside and inside domains of an epithelial surface. An experimental epithelial-like surface can be generated *in vitro* with autonomously replicating cell lines (*e.g.*, MDCK, ATCC No. CCL 34; HEC-1A, ATCC No. HTB 112), which form epithelial-like surfaces in culture, have tight junctions and articulate one free (apical) and one adherent (basolateral) domain.

[0019] Apical domain: The outside of an epithelial surface which is adjacent to the environment external to the body or to the volume of a body cavity or body tube. The outside of the cells, as delimited by the zonula occludens, is composed of the coating substances, secretions and cell membranes facing the outside of the epithelial surface.

[0020] Luminal compartment: The inner space of a body tube, cavity or duct lined by an epithelial surface and adjacent to the apical domain.

[0021] Basolateral domain: The inside of the epithelial surface which is delimited from the apical domain by the zonula occludens. The basolateral domain is adjacent to the basement membrane and is exposed to interstitial fluids and components of the tissues underlying epithelial surfaces. The basolateral domain is the inner side of cells of an epidermal surface.

[0022] Basolateral membrane: The portion of the plasma membrane of a cell of an epithelial surface which is within the basolateral domain.

[0023] Basolateral factor: A component of the basolateral domain which is a naturally occurring element of a basolateral membrane *in vivo*. A "basolateral factor associated with an epithelial surface" refers to a basolateral factor attached by covalent or noncovalent bonds to the basolateral domain, or a component of the membrane proper in a basolateral domain.

[0024] Internalization: The process of uptake into a cell compartment that is bounded by a plasma membrane.

[0025] Specific binding: A TM specifically binds to a basolateral domain if it specifically interacts at the basolateral domain of an epithelial surface. Both quantitative and qualitative assays may be used to distinguish specific binding from binding which is not specific within the context of the subject invention. A quantitative measurement of binding affinity (k_{aff}) may be used to identify components that bind specifically. In general, a k_{aff} of 10^4 M^{-1} or higher constitutes specific binding between two binding components. The binding affinity for the cognate components of a binding interaction can be estimated experimentally by a variety of methods that are well known in the art, including equilibrium dialysis assays, precipitation radioimmunoassays, assays with immobilized ligands, assays with isolated cells or

membranes, ELISAs, or by other direct or indirect measurements or binding (*e.g.*, plasmon resonance).

[0026] Qualitative specificity of binding is demonstrated by differential, or asymmetric distribution of binding of a factor among two or more chemical, spatial or temporal domains. This differential distribution can be observed visually, or by chemical or physical means, and generally reflects approximately a 3 to 1 or greater differential in signal intensity between basolateral and non-basolateral domains. Such qualitative specificity may result from substantial differences in the affinity of binding of an agent to one of several domains, or to the number or availability of cognate binding sites on a domain. The qualitative specificity of binding of an agent among several domains can be observed in a competition experiment. In such an experiment a TM is allowed to distribute among domains, and at equilibrium is observed to preferentially bind to one domain over another.

[0027] Targeting Molecule (TM): A molecule capable of specifically binding to a cognate factor on epithelial surfaces, which is not uniformly distributed.

[0028] Imaging agent: Any substance administered to illuminate a physiological function within a patient, while leaving other physiological functions generally unaffected.

[0029] Linked: An imaging agent is linked to a TM if it is attached covalently, by ionic interaction and/or by hydrophobic interactions, or by other means such that under physiological conditions of pH, ionic strength and osmotic potential the linked entities are associated with each other at equilibrium. TMs as described herein are generally capable of specifically binding to a factor preferentially distributed on an epithelial surface, such as a basolateral factor. Through binding to such a factor, TMs are capable of causing the internalization of an imaging agent linked to the TM. TMs as described herein have a distinct three-dimensional structure. In general, TMs comprise a polypeptide that forms a closed covalent loop which is referred to herein as the "core." All subunits of the polypeptide may, but need not, be connected by identical chemical bonds. In a preferred embodiment, the polypeptide comprises amino and/or imino acids covalently joined by peptide bonds and one or more cystine disulfide bridges.

[0030] The core of a TM typically contains at least three peptide domains having β -sheet character, interspersed among regions lacking β -sheet character. In this regard, a "peptide domain" is a portion of a polypeptide comprising at least three amino acid residues. A peptide domain is said to have β -sheet character if the peptide backbone has an extended conformation with side-chain groups in a near planar and alternating arrangement such that hydrogen bonding can occur between carbonyl and NH groups of the backbone of adjacent β -strands. Furthermore, TMs generally contain at least one cysteine residue not present within an intramolecular cystine. Such cysteine(s) may be used for linking one or more imaging agents to the TM, although other means of linking imaging agents are also contemplated.

[0031] One or more of a variety of other structures may, but need not, be additionally present within a TM. For example, a second peptide loop may be present within the core sequence. Additional N-terminal and/or C-terminal sequences may be present. If present, N-terminal sequences are usually linear. A preferred N-terminal sequence is a short (about 1-20 amino acid residues) peptide domain. C terminal sequences may be linear and/or may form one or more loops. Such sequences may, but need not, possess domains having β -sheet character. These and/or other protein domains may be added to the core by genetic means or chemically, using covalent bonds or noncovalent interactions.

[0032] In a preferred embodiment, a TM comprises all or a portion of a native J chain sequence, or a variant thereof. J chain is a 15 kD protein that, *in vivo*, links IgM or IgA monomers to form pentameric IgM or dimeric IgA (*see* Max and Korsmeyer, *J. Exp. Med.* 161:832-849, 1985). To date, sequences of J chains from six organisms have been deduced (*see* Figure 1 and SEQ ID NO:1 - SEQ ID NO:6; Kulseth and Rogne, *DNA and Cell Biol.* 13:37-42, 1994; Matsuuchi et al., *Proc. Natl. Acad. Sci. USA* 83:456-460, 1986; Max and Korsmeyer, *J. Exp. Med.* 161:832-849, 1985; Hughes et al., *Biochem J.* 271:641-647, 1990; Mikoryak et al., *J. Immunol.* 140:4279-4285, 1988; Takahashi et al., *Proc. Natl. Acad. Sci. USA* 93:1886-1891, 1996). A TM may comprise a native J chain from one of these organisms, or from any other organism.

[0033] Alternatively, a TM may comprise a portion or variant of a native J chain sequence. A variant is a polypeptide that differs from a native a sequence only in one or

more substitutions and/or modifications. Portions and variants of the native J chain sequence contemplated by the present invention are those that substantially retain the ability of the native J chain to specifically bind to a basolateral factor associated with an epithelial surface, and cause the internalization of a linked imaging agent. Such portions and variants may be identified using, for example, the representative assays described herein.

[0034] Within the context of the TM compositions provided herein, the TM is not full length dimeric IgA. More specifically, the TM does not contain all of the components present within a naturally-occurring IgA (*i.e.*, a heavy chain containing contiguous variable, C_{H1}α, C_{H2}α and C_{H3}α domains and a light chain containing contiguous variable and C_L domains). Such a TM may, of course, contain one or more portions of an IgA molecule, including an IgM.

[0035] As noted above, specific binding may be evaluated using quantitative and/or qualitative methods. In one representative quantitative assay, secretory component (SC) isolated from human milk by standard immunoaffinity chromatography methods (Underdown, B.J., DeRose, J., Koczekan, K., Socken, D., Weicker, J., *Immunochemistry* 14:111-120, 1977) is immobilized on a CM5 sensor chip with a BIACORE apparatus (Pharmacia, Piscataway, NJ) by primary amine coupling. The sensor chip is activated by injection of 30 μL of 0.05M N-hydroxysuccinimide and N-ethyl-N-(3-diethylaminopropyl)carbodiimide, followed by injection of 25 μL of human SC (15 μg/mL) in 10 mM sodium acetate, pH 5.0. Unreacted carbodiimide is then quenched with 30 μL ethanolamine. All reagents are delivered at a flow rate of 5 μL per minute. To evaluate the kinetics of binding and desorption, serial two fold dilutions of TMs at concentrations between 100 μM and 100 nM are injected in binding buffer: 25mM Tris, pH 7.2, 100mM NaCl, 10mM MgCl₂ at a flow rate of 20 μL per minute. Between dilutions, the surface is regenerated by injecting 50 μL of 25 mM Tris, pH 7.2, 200 mM NaCl, 2M urea, followed by injecting 50 μL of binding buffer. Association and dissociation constants are derived from sensograms using BIAevaluation 2.1 software to derive simple association(k_a) and dissociation constants(k_d). The K_{aff} is estimated as k_a/k_d .

[0036] In one representative qualitative assay, monolayers of HEC-1 A cells can be used to measure qualitative binding of TMs. The procedure is based on previously published protocols (*see* Ball et al., *In Vitro Cell Biol.* 31: 96, 1995). HEC-1A cells are cultured on 24 mm filter transwells (Costar, #3412, 0.4 μ m) for one week until cells are confluent. Monolayer-covered filter transwells are washed twice on both surfaces with cold PBS (4°C). One ml of cold MEM-BSA containing 1.0 μ g of biotinylated ligand is added to the apical chamber and 1.5 ml cold MEM-BSA buffer (MEM-BSA (4°C): minimum essential medium with hank's salts, and 25 mM HEPES buffer without L-glutamine (Life Technologies, Gaithersburg, MD Cat. No. 12370) containing 0.5% BSA, which is treated at 56°C for 30 min to inactivate endogenous protease and filter sterilized) containing 1.5 μ g of biotinylated ligand is added to the basolateral chamber. The cultures are kept at 4°C for 2 hours to achieve maximum binding in the absence of internalization. The medium is removed from both chambers, and the filters are washed twice with cold PBS. Filters are then remove from the transwell supports with a scalpel and incubated with a streptavidin-fluorescein conjugate (#21223, Pierce Chemical Company, Rockford, IL), 0.1 μ g/mL in cold PBS, then washed 3 times with cold PBS. 1cm square pieces of filter are then cut from the 24mm filter and mounted on microscope slides and observed microscopically under epifluorescence illumination(excitation 490nm, emission 520nm). Under these conditions the apical membranes show little or no fluorescence, while basolateral membranes demonstrate bright fluorescence (*i.e.*, greater than a 3 to 1 differential in signal intensity) indicating specific binding to the basolateral domain. Similar assays can be employed with isolated epithelial tissues from gastrointestinal, oral or bronchial epithelial tissue layers.

[0037] Once bound to the basolateral domain of an epithelial cell, a TM may be internalized within a cell of an epithelium-like monolayer. Suitable cells for evaluating internalization include MDCK cells expressing the human polyimmunoglobulin receptor (pIgR) (*see* Tamer et al., *J. Immunol* 155:707-714, 1995) and HEC1-A cells. One assay in which internalization can be observed employs a HEC1-A cell line grown to confluent monolayers on permeable membrane supports (such as Costar, Cambridge, MA, #3412). Briefly, 100 ng to 10 μ g of a TM (*e.g.*, fluorescein labeled) may be added to 1.5 mL of assay buffer in the basolateral compartment of cell monolayers and

incubated at a temperature that allows binding and internalization of TMs, but that inhibits transcytosis (*e.g.*, 90 minutes at 16°C). The medium from both compartments is then removed and the filter membranes washed (*e.g.*, twice at 4°C with PBS). The membrane is immersed in a fixation solution of, for example, 3% (w/v) paraformaldehyde, 1% (w/v) glutaraldehyde, 5% (w/v) sucrose, 100 mM Na phosphate pH 7.4 on ice for 30 minutes. The membranes may be removed from the plastic insert by cutting around the periphery with a scalpel and cut into 5 mm square sections. These wholemount sections may be placed on microscope slides and observed microscopically under epifluorescence illumination (excitation 490 nm, emission 520 nm) or by fluorescence confocal microscopy. Internalized TM is indicated by the presence of bright green-yellow fluorescence in intracellular vesicles.

[0038] Substitutions and modifications that result in a variant that retains the qualitative binding specificity for a basolateral factor (*i.e.*, at least a 3 to 1 differential in signal intensity between basolateral and non-basolateral domains) are considered to be conservative. Preferred conservative substitutions and modifications include alterations in a sequence that render it, at least in part, consistent with the J chains of one or more other species. A TM may also, or alternatively, contain other sequences that confer properties not present in a native J chain. Other preferred modifications include the addition of one or more protein domains at the N- and/or C-terminus and/or altering the order of domains present within a native J chain sequence. A variant may contain any combination of such substitution(s) and/or modification(s), provided that the ability of the variant to specifically bind to an epithelial basolateral factor and cause internalization of the linked imaging agent is not substantially reduced.

[0039] A native J chain typically has 6 domains. The first (N-terminal) domain is a short linear (*i.e.*, as contrasted to a loop) peptide that serves (*in vivo*) as the junction between the signal peptide and the core TM molecule. Domain 1 typically contains 1-20 amino acid residues, and the first amino acid is generally D, E or Q. In Figure 1, Domain 1 contains the amino acids up to and including residue number 11. Domain 1 is not essential for TM function, and variants that do not contain this domain are within the scope of the present invention.

[0040] Domain 2 typically contains 90 amino acids, and possesses substantial β -sheet character. This β -sheet region contains peptides of varying length lacking β -strand character (*e.g.*, residues 26-31, 49-53), the peptides usually containing polar and/or charged amino acids. In a TM, Domain 2 is a covalently closed peptide loop, called the core, which is typically formed by an intramolecular cystine composed of the initial and ultimate residues of Domain 2 (residues 12 and 101 of Figure 1). Within Domain 2, there may be another cystine bond that defines Domain 3, a peptide loop that is nested within the core. It has been found, within the context of the present invention, that the core (with or without Domain 3) is sufficient to provide TM function. Accordingly, a preferred TM contains Domain 2 (*i.e.*, residues 12-70 and 92-101 of Figure 1), or a portion or variant thereof that substantially retains TM function.

[0041] Within Domain 2, the second cysteine is generally separated from the initial cysteine of Domain 2 by a single amino acid residue (*see*, for instance, Figure 1). Between the second and third cysteines of Domain 2 is a region of primarily β -sheet character. These two cysteines (2 and 3) when present, typically do not form cystines within the core. The fourth cysteine is typically separated from the third cysteine by two basic amino acid residues and initiates Domain 3. Domain 3 ends with the fifth cysteine which is oxidized by the fourth cysteine. The resulting cystine forms a covalent peptide loop defining Domain 3 contained completely within Domain 2. Cysteine 6 is the ultimate residue of Domain 2, and is oxidized to cystine by the initial residue of Domain 2.

[0042] Within the core is a canonical peptide sequence for N-linked glycosylation (*e.g.*, NIS). When produced by eukaryotic cells, carbohydrate moieties can be covalently attached to an N residue of a TM at this site.

[0043] When present, Domain 3 is typically a peptide 21 amino acids in length. This domain is delimited by amino and carboxy terminal cysteine residues which form an intramolecular cystine bond that is contained completely within the core.

[0044] Domains 4-6 are carboxy terminal domains in native J chains which may, but need not, be present within a TM. Domain 4 is typically a peptide of seven amino acids. In native J chains, this peptide contains no cysteine residues and connects the core to Domain 5. Domain 5 is, when present, typically a peptide of 26 amino acids

delimited by amino and carboxy terminal cysteine residues which form an intramolecular cystine bond resulting in a covalently closed loop. In native J chains, the amino and carboxy terminal portions of Domain 5 have substantial β -sheet character and are separated by a short 3-6 residue peptide with low β -sheet propensity. Domain 6 is typically a short peptide of five amino acids or less which serves as the carboxy terminus of a TM. Domains 4-6 are not essential for TM function.

[0045] As noted above, numerous variants of native J chain sequences may be employed within TMs as described herein. For example, a TM core, as described above, can serve as a molecular scaffolding for the attachment and/or substitution of Domains and/or additional molecular components. Possible variants include:

- TMs in which Domain 1 comprises a peptide of about 13 amino acids, the middle third of which has substantial β -sheet character (*e.g.*, DQEDERIVLVDNK; SEQ ID NO:37);
- TMs in which the asparagine residue at position 48 is changed to histidine (*e.g.*, AAT to CAC);
- TMs in which Domain 1 comprises a three amino acid peptide DNK;
- TMs in which Domain 1 contains a peptide with a sequence specific for recognition and cleavage by a protease which can be used to release distal portion of the TM from a proximal colinear peptide or protein (*e.g.*, a peptide recognized by the tobacco etch virus protease Nia: ENLYFQS; SEQ ID NO:38);
- TMs in which Domain 1 contains a peptide sequence which specifies the intracellular targeting of the contiguous peptide (*e.g.*, a nuclear targeting peptide);
- TMs in which one or both of the native cysteine residues 2 or 3 within Domain 2 are removed or replaced to eliminate the possibility of intermolecular crosslinking (*e.g.*, substitutions of S, T, A, V or M residues for the native C);
- TMs in which a portion of Domain 3 is deleted, such that there is a peptide bond between the amino acid distal to the end of the third β -sheet of Domain 3 and the initial residue of the ultimate peptide of Domain 3;
- TMs in which other peptides that form loop structures or other antiparallel peptide domains are included in place of Domain 3, or between its defining cysteines, to

provide functionalities or recognition domains to the TM (*e.g.*, viral capsid protein loops);

- TMs in which Domain 4 is truncated to form a TM without Domains 5 and 6;
- TMs in which Domain 4 is replaced as described above for Domain 3 to introduce a new functionality, specificity and/or structure to the TM;
- TMs in which Domain 4 contains a proteolytic site specific for a cellular compartment which would result in cleavage of the TM into two molecules in a cellular compartment;
- TMs in which the loop structure of Domain 5 is replaced with a peptide sequence to provide functionalities or recognition domains to the TM (*e.g.*, single chain antibody variable region or viral capsid protein loop);
- TMs in which Domain 6 is terminated in a peptide sequence or is replaced with a peptide sequence that would target the contiguous TM protein to an intracellular target (*e.g.*, KDEL, SEQ ID NO:44, or HDEL, SEQ ID NO:86, for retention in the endomembrane system);
- TMs that additionally comprise one or more immunoglobulin-derived sequences (*e.g.*, domains of the Ig heavy chain classes: alpha3, alpha2, alpha1, mu4, mu3, mu2, mu1) linked via one or more disulfide and/or peptide bonds. Such sequences may serve as attachment sites for one or more biological agents.

[0046] The above list of representative variants is provided solely for illustrative purposes. Those of ordinary skill in the art will recognize that the modifications recited above may be combined within a single TM and that many other variants may be employed in the context of the present invention.

[0047] TMs may generally be prepared using any of a variety of well known purification, chemical and/or recombinant methods. Naturally-occurring TMs (*e.g.*, human J chain) may be purified from suitable biological materials, as described herein. All or part of a TM can be synthesized in living cells, with the sequence and content defined by the universal genetic code, a subset of the genetic code or a modified genetic code specific for the living cells. Any of a variety of expression vectors known to those of ordinary skill in the art may be employed to achieve expression in any appropriate

host cell. Suitable host cells include insect cells, yeast cells, mammalian cells, plant cells, algae, bacteria and other animal cells (*e.g.*, hybridoma, CHO, myeloma).

[0048] An example of a synthetic gene encoding a targeting molecule is provided in SEQ ID NO:7. Such synthetic genes may be ligated into, for example, a polyhedrin-based baculovirus transfer vector such as pMelBac A, pMelBac B or pMelBac C (Invitrogen, San Diego, CA) between suitable restriction sites (*e.g.*, the BamHI and SalI sites) and introduced into insect cells such as High Five, Sf9 or Sf21 in a cotransfection event using Bac-N-Blu AcMNPV DNA (Invitrogen, San Diego, CA) according to standard methods. Other suitable vectors and host cells will be readily apparent to those of ordinary skill in the art.

[0049] Synthetic polypeptide TMs or portions thereof having fewer than about 100 amino acids, and generally fewer than about 50 amino acids, may be generated using synthetic techniques well known to those of ordinary skill in the art. For example, such polypeptides may be synthesized using any of the commercially available solid-phase techniques, such as the Merrifield solid-phase synthesis method, where amino acids are sequentially added to a growing amino acid chain. *See Merrifield, J. Am. Chem. Soc.* 85:2149-2146, 1963. Equipment for automated synthesis of polypeptides is readily available from suppliers such as Applied BioSystems, Inc., Foster City, CA, and may be operated according to the manufacturer's instructions.

[0050] Linkage of a TM to one or more imaging agents may be achieved by any means known to those in the art, such as genetic fusion, covalent chemical attachment, noncovalent attachment (*e.g.*, adsorption) or a combination of such means. Selection of a method for linking a TM to an imaging agent will vary depending, in part, on the chemical nature of the agent and depending on whether the agent is to function at the basolateral surface, within the epithelial cell, or undergo transcytosis. Linkage by genetic fusion may be performed using standard recombinant DNA techniques to generate a nucleic acid molecule that encodes a single fusion peptide containing both the imaging agent(s) and the TM. Optionally, a TM may also be linked to one or more linker sequences and/or sequences for intracellular targeting (*e.g.*, KDEL, protease cleavage sites, etc.). Such sequences may be linked to a TM by genetic fusion using standard recombinant DNA techniques to generate a nucleic acid molecule encoding the

TM and the desired additional sequences. The recombinant nucleic acid molecule is then introduced into an appropriate vector and expressed in suitable host cells. Techniques for generating such a recombinant molecule and expressing a fusion peptide are well known to those of ordinary skill in the art (*see, e.g.,* Sambrook et al., *Molecular Cloning: A Laboratory Manual*, 2d ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, NY, 1989). Any imaging agent having a known polypeptide sequence may be linked to a TM by genetic fusion.

[0051] Linkage may also be achieved by covalent attachment, using any of a variety of appropriate methods. For example, the TM and imaging agent(s) may be linked using bifunctional reagents (linkers) that are capable of reacting with both the TM and the imaging agent(s) and forming a bridge between the two. For delivery of agents that will remain within the epithelial cell, linkers that are cleaved within the target cell may be particularly useful. Covalent attachment of linkers may be accomplished through bonding to amino acid side chains present in the antigen combining site of an antibody linked to a TM. Briefly, attachment of linkers to these residues can occur as a result of the antibody recognition process itself when the linker is recognized as antigen and compatible reactive residues are present on the linker-antigen and in the binding domain of the antibody. Such reactive antibodies typically have antigen combining sites containing amino acid residues with side chains which can act as nucleophiles (*e.g.,* aspartate, glutamate, glutamine, lysine and/or asparagine).

[0052] Any of a variety of molecules may serve as linkers within the present invention. Polynucleotide and/or peptide linkers may be used. Such molecules may then be digested by, for example, intestinal nucleases and proteases (*e.g.,* enterokinase, trypsin) respectively to release the imaging agent. Preferred linkers include substrates for intracellular proteases associated with an epithelial barrier (*i.e.,* proteases resident in or on epithelial cells or surfaces, or in the extracellular fluids exposed to the apical or basolateral domains). Numerous proteases are present in or associated with epithelial cells. For example, linkers can be derived from the sequences of the extracellular matrix (ECM) proteins which are acted on by specific secreted proteases. Some secreted proteases are especially active in the extracellular fluids adjacent to cancerous epithelial cells which are becoming metastatic (*e.g.,* gelatinase A, gelatinase B,

matrilysin, stromelysin-1, stromelysin-2, stromelysin-3, collagenase-3, membrane-type matrix metalloproteinase). These proteases degrade ECM components with which the basolateral domain of epithelial cells associate (*e.g.*, the basement membrane). This degradation is prerequisite to cellular release from the epithelial surface and thus to subsequent intravasation and metastasis. Proteolytic cleavage sites of these proteases can be identified by evaluation of the amino acid sequence of the cleavage products and comparison of these sequences to the sequences of the ECM substrate. These cleavage sites are particularly useful in scissile linkers which allow efficient cleavage from TM of imaging agents in epithelial regions where these proteases are active, delivering an imaging agent to the basolateral domain. Imaging agents linked to TM with such linkers associate with basolateral factors in other epithelial regions, but are transported through the epithelial barrier and do not remain associated with the basolateral domain.

[0053] Processing of secreted proteins requires proteolytic scission of a portion of the newly synthesized protein (referred to as the pre-protein) prior to secretion from the cellular endomembrane system. Further processing, which may be required to liberate an active enzyme from the cell, for example, can result from additional proteolysis wherein the substrate may be referred to as the pro-protein or pro-enzyme. The specific proteolytic cleavage sites of these pro-proteins can be identified by comparison of the amino acid sequence of the final secreted protein with the sequence of the newly synthesized protein. These cleavage sites identify the substrate recognition sequences of particular intracellular proteases. One such protease recognition site, specific to epithelial cells, is the amino acid sequence from residues 585-600 of the human polyimmunoglobulin receptor (pIgR (SEQ ID NO:45); numbering according to Piskurich et al., *J. Immunol.* 154:1735-1747, 1995). Another such protease recognition site, which identifies proteases abundant in cancer cells, comprises residues 30-40 of procathepsin E (SEQ ID NO:39). Since cancer cells secrete abundant quantities of proteases, the intracellular proteases which are responsible for their processing are also in abundance.

[0054] These protease recognition sites are extremely useful in the design of scissile linkers enabling the delivery of imaging agents to the intracellular environment of epithelial cells or to the epithelial barrier in general. Delivery of such compounds to

epithelial cells can be accomplished by using residues 585-600 of human pIgR (SEQ ID NO:45) or residues 30-40 of procathepsin E (SEQ ID NO:39) as part of the scissile linker joining the imaging agent to TM. Alternatively, scissile linkers may be designed from other cancer cell specific or epithelial barrier specific processing proteases which may be identified by the comparison of newly synthesized and secreted proteins or similar techniques. Other types of proteases that can be used to cleave scissile bonds can be found in the mammalian duodenum, for example. The enterokinase recognition sequence, (Asp)₄-lys, can be used as a scissile linker for delivery of imaging agents to the duodenum by TM mediated transcytosis across the duodenum epithelial barrier.

[0055] Scissile peptide linkers are generally from about 5 to about 50 amino acid residues in length. They can be covalently linked to TM or to adducts attached to TM by genetic fusion techniques (*i.e.*, in frame with the 5' or 3' sequence of TM codons or adduct codons) or by any of a variety of chemical procedures enabling the joining of various functional groups (*e.g.*, NH₂, COOH, SH).

[0056] Other substrates for intracellular proteases associated with an epithelial barrier include, but are not limited to, substrates for a phospholipase or glycosidase. Proteolytic cleavage releases the imaging agent with a small fragment of linker (*e.g.*, VQYT (SEQ ID NO:40) from procathepsin, EKAVAD (SEQ ID NO:41) from pIgR). Alternatively, a linker may comprise repeating positively charged lysine residues that will bind negatively charged nucleic acid molecules for release in the cell. Peptide linkers may be particularly useful for peptide imaging agents.

[0057] Carbohydrates may be covalently attached to native carbohydrate or to the polypeptide backbone of a TM, and employed as linkers. Suitable carbohydrates include, but are not limited to, lactose (which may degraded by a lactase residing in, for example, the small intestine), sucrose (digested by a sucrase) and α -limit dextrin (digested by a dextrinase). Enzymes responsible for cleaving carbohydrate linkers can be found attached to the brush border membranes of the luminal surface of the epithelial barrier. Sucrase-isomaltase, for example, will cleave 1,4- α bonds of maltose, maltotriose and maltopentose. An intestinal brush border specific linker would therefore be comprised of any polymer of maltose linked by 1,4- α bonds. When attached to TM, the linker would pass through the epithelial barrier by transcytosis and

would only be cleaved by sucrase-isomaltase resident on the apical surface of the epithelial barrier.

[0058] Lipids may also, or alternatively, be covalently attached to the polypeptide backbone for use as linkers. A monoglyceride employed in this manner may then be digested by intestinal lipase to release an imaging agent linked to glycerol or a fatty acid. Phospholipids may be attached to a TM via a peptide linkage to the phosphatidylserine polar head group or by an ether or ester linkage to one of the hydroxyl groups of the head group of phosphatidyl inositol. The non-polar head group (diacylglycerol) may be substituted entirely by the imaging agent in active or inactive form. Other suitable linker moieties will be apparent to those of ordinary skill in the art.

[0059] Linkage may also be performed by forming a covalent bond directly between a TM and an imaging agent. Regardless of whether a linker is employed, any of a variety of standard methods may be used to form a covalent linkage. For peptide imaging agents and linkers, such a covalent bond may be a disulfide bond between cysteine residues of the TM and the imaging agent. Briefly, such bonds may be formed during the process of secretion from the endomembrane system of higher organisms. In such cases, the peptide biological agent(s) and TM must contain appropriate signals specifying synthesis on endomembranes. Such signals are well known to those of ordinary skill in the art. Alternatively, free amino or sulfhydryl groups of a TM may be covalently linked to a reactive group of an imaging agent, using standard techniques. For example, reaction of free amino groups of a TM with the NHS moiety of NHS-cyanine will result in covalent attachment. Alternatively, cyanine dyes can be derivatized to contain sulfhydryl reactive components (*e.g.*, sulfo-MBS (Pierce Chemical Co., Rockford, IL; or by reaction with SPDP [N-succinimidyl-3-[2-pyridylthio]propionate]), which can be used for attachment to free sulfhydryls of a TM.

[0060] Reactive antibodies may covalently attach directly to an imaging agent or a linker. Antibodies raised against antigens containing reactive groups or transition state analogs for specific reactions may contain residues in the combining site capable of forming covalent interactions with the antigen or with similar molecules. An example of such a reaction occurs between a lysine residue in the combining site of the monoclonal antibody 38C2 which reacts to form a vinylogous amide linkage with

diketone and other closely related molecules (Wagner et al., *Science* 270:1797-1800, 1995). A TM containing a reactive antibody or the combining site of a reactive antibody can be used to form covalent bonds with linkers of lipid, peptide, carbohydrate, nucleic acid or other compositions. TMs containing imaging agents attached to TM via covalent bonds in the combining site can be expected to have normal conformations and functions in the antibody domain. The absence of modifications to antibody structure outside the antigen combining site may minimize the potential for altering the recognition of such molecules as foreign when introduced into the body. Further, antibodies of human origin with reactive site tethered imaging agents could be expected to have half-lives in serum and other body compartments similar to those of native antibodies and have low propensity to stimulate antibody responses against the TM.

[0061] As noted above, any diagnostic imaging agent may be linked to a TM. Imaging agents include metals, radioactive isotopes and radioopaque agents (*e.g.*, gallium, technetium, indium, strontium, iodine, barium, bromine and phosphorus-containing compounds), radiolucent agents, contrast agents, dyes (*e.g.*, fluorescent dyes and chromophores) and enzymes that catalyze a colorimetric or fluorometric reaction. In general, such agents may be attached using a variety of techniques as described above, and may be present in any orientation.

[0062] In one preferred embodiment, a targeting molecule as described above is linked to a imaging agent that is not naturally associated with the targeting molecule. Within the context of this embodiment, the imaging agent is not iodine.

[0063] An imaging agent linked to a TM is generally administered to a patient in the form of a pharmaceutical composition. To prepare a pharmaceutical composition, one or more TM-imaging agent complexes are mixed with a suitable pharmaceutical carrier or vehicle. Pharmaceutical carriers or vehicles include any such carriers known to those skilled in the art to be suitable for the particular mode of administration.

[0064] The compositions of the present invention may be prepared for administration by a variety of different routes, including orally, parenterally, intravenously, intradermally, subcutaneously or topically, in liquid, semi-liquid or solid

form and are formulated in a manner suitable for each route of administration. Preferred modes of administration depend upon the indication treated.

[0065] Solutions or suspensions used for oral, parenteral, intradermal, subcutaneous or topical application can include one or more of the following components: a sterile diluent, saline solution (*e.g.*, phosphate buffered saline), fixed oil, polyethylene glycol, glycerin, propylene glycol or other synthetic solvent; antimicrobial agents, such as benzyl alcohol and methyl parabens; antioxidants, such as ascorbic acid and sodium bisulfite; chelating agents, such as ethylenediaminetetraacetic acid (EDTA); buffers, such as acetates, citrates and phosphates; and agents for the adjustment of toxicity such as sodium chloride or dextrose. In addition, other pharmaceutically active ingredients and/or suitable excipients such as salts, buffers, stabilizers and the like may, but need not, be present within the composition. Liposomal suspensions may also be suitable as pharmaceutically acceptable carriers. These may be prepared according to methods known to those skilled in the art.

[0066] A TM may be prepared with carriers that protect it against rapid elimination from the body, such as time release formulations or coatings. Such carriers include controlled release formulations, such as, but not limited to, implants and microencapsulated delivery systems, and biodegradable, biocompatible polymers, such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, polyorthoesters, polylactic acid and others.

[0067] A pharmaceutical composition is generally formulated and administered to exert a useful effect while minimizing undesirable side effects. The number and degree of acceptable side effects depends upon the condition to be diagnosed. For example, certain toxic and undesirable side effects are tolerated when diagnosing life-threatening illnesses, such as tumors, that would not be tolerated when diagnosing disorders of lesser consequence. The concentration of imaging agent in the composition will depend on absorption, inactivation and excretion rates thereof, the dosage schedule and the amount administered, as well as other factors known to those of skill in the art.

[0068] The composition may be administered one time, or may be divided into a number of smaller doses to be administered at intervals of time. The precise dosage and duration of administration is a function of the disease being diagnosed and may be

determined empirically using known testing protocols or by extrapolation from *in vivo* or *in vitro* test data. For any particular subject, specific dosage regimens may be adjusted over time according to the individual need of the patient.

[0069] The following Examples are offered by way of illustration and not by way of limitation.

EXAMPLES

Example 1

Preparation of Targeting Molecules

[0070] This Example illustrates the preparation of representative targeting molecules.

A. Purification of Representative TMs from Biological Sources

[0071] *Preparation of dimeric IgA (dIgA).* Ten ml of human IgA myeloma plasma (International Enzymes, Inc.; Fallbrook, CA) is mixed with an equal volume of PBS, and 20 ml of saturated ammonium sulfate (in H₂O) is added dropwise with stirring. After overnight incubation at 4°C, the precipitate is pelleted by centrifugation at 17,000 x g for 15 minutes, and the supernatant fraction is discarded. The pellet is resuspended in 2 ml PBS. The resulting fraction is clarified by centrifugation at 13,500 x g for 5 minutes and passage through a 0.45µm filter (Nylon 66, 13mm diameter, Micron Separations, Inc., Westborough, MA). Two ml (about half) of the clarified fraction is applied to a Sephacryl[®] S-200 column (1.6 x 51 cm; 0.25 ml/min PBS+ 0.1% sodium azide) (Pharmacia, Piscataway, NJ), and 2 ml fractions are collected. Those fractions found to have the highest concentrations of dIgA (by SDS-PAGE analysis of 10 µl of each fraction) are lyophilized, resuspended in 200 µl deionized H₂O, and applied to a Superose[®] 6 column (1.0 x 30 cm; 0.25 ml/min PBS+0.1% sodium azide) (Pharmacia, Piscataway, NJ). One ml fractions are collected and analyzed by SDS-PAGE. Fraction 13 is found to contain dIgA at over 90% purity.

[0072] *Preparation of J chain by mild reduction of dIgA.* A 1 ml sample containing less than 10 mg of dIgA is prepared as described above and dialyzed against

buffer containing 100 mM sodium phosphate pH 6.0 and 5 mM EDTA. Six mg 2-mercaptoethylamine HCl are added to yield a final concentration of 0.05M, and the sample is incubated at 37°C for 90 minutes. The reduced protein is passed over a desalting column equilibrated in PBS + 1mM EDTA. The protein-containing fractions are detected by assay with BCA reagent. J chain is then further purified by gel filtration and ion exchange chromatography.

[0073] *Preparation of secretory IgA (sIgA).* One hundred ml of human breast milk (Lee Scientific, Inc.; St. Louis, MO) is mixed with 100 ml PBS and centrifuged at 17,000 x g for 1 hour at 4°C. The clear layer below the fat is transferred to clean centrifuge bottles and centrifuged at 17,000 x g for 30 minutes at 4°C. The pH of the sample is adjusted to 4.2 with 2% acetic acid. After incubation at 4°C for 1 hour, the sample is centrifuged at 17,000 x g for 1 hour at 4°C, and the supernatant fraction is transferred to new tubes and adjusted to pH 7 with 0.1M NaOH. An equal volume of saturated ammonium sulfate is added, with stirring, and the sample is incubated at 4°C overnight. The precipitated material is pelleted by centrifugation (17,000 x g, 90 minutes, 4°C), resuspended in approximately 7 ml PBS, and dialyzed extensively against PBS at 4°C.

[0074] Of the resulting approximately 25 ml, 1.1 ml is further purified. Undissolved solids are removed by centrifugation (13,500 x g, 10 minutes) and an equal volume of 0.05 M ZnSO₄ is added to the clarified supernatant fraction. The pH is adjusted to 6.85 by addition of approximately 40 µl 1 M NaOH. After allowing the material to sit for 5 minutes at room temperature, the sample is centrifuged at 13,500 x g for 10 minutes at room temperature. One and a half ml of the supernatant is mixed with 1.5 ml of saturated ammonium sulfate and allowed to stand at 4°C for 1 hour. Precipitating material is pelleted by centrifugation (13,500 x g, 10 minutes, room temperature) and is found to be greater than 90% sIgA by SDS-PAGE analysis.

[0075] *Preparation of a molecule consisting of nicked J-chain crosslinked to two alpha-chain-derived peptides (CNBr cleavage fragment).* A pellet containing sIgA prepared as described above ("Preparation of sIgA") is resuspended in 375 µl deionized H₂O. The sample is transferred to a glass vial and the vial is filled almost to the rim

with 875 μ l formic acid. Approximately 20 mg solid CNBr is added and a Teflon septum is used to seal the vial. The reaction is allowed to proceed at 4°C overnight. The sample is then dialyzed against deionized H₂O (two changes) and against PBS at 4°C, and lyophilized, resuspended with 200 μ l H₂O, and applied to a Superose® 6 column (1.0 x 30 cm, 0.25 ml/min PBS + 0.1% sodium azide). One ml fractions are collected. The fractions containing J chain are identified by immunoblotting of SDS-PAGE-separated proteins from aliquots of each fraction.

[0076] The fraction with the highest concentration of J chain is passed through a PD-10 column (Pharmacia, Uppsala, Sweden) equilibrated in 50 mM Tris-Cl pH 8.1, and applied to a 20 PI Poros anion exchange column (4.6 mm x 100 mm; PerSeptive Biosystems, Inc., Framingham, MA). The column is washed with 10 ml of 50 mM Tris-Cl pH 8.1, and eluted with a linear 0 - 1.0 M NaCl gradient in 50 mM Tris-Cl pH 8.1 (15 ml gradient). Elution of proteins from the column is monitored as absorbance at 280 nm and the J chain-containing fractions are identified by immunoblotting of SDS-PAGE-separated aliquots.

[0077] *Alternative Methods for J Chain Purification.* A variety of sources are suitable as starting material for isolation of human J chain. Polymeric IgA from sera of patients with IgA multiple myeloma, secretory IgA or IgM from sera of patients with Waldenstroms macroglobulinemia, as well as secretory IgA from human breast milk can be used as starting material for purification of J chain. Although the differences in the molecular weights of J chain (16,000) and L chains (22,500) should be large enough to allow satisfactory separation of these two chains by gel filtration, the unique conformation of J chain and its ability to dimerize often results in co-elution of J chain with L chain. Isolation procedures take advantage of J chain's negative charge (due to the high content of aspartic and glutamic acid residue) further increased by S-sulfitolysis or alkylation of reduced cysteine residues with iodoacetic acid. J chain can be subsequently separated from H and L chains by DEAE- or CM-cellulose chromatography using a linear salt gradient or by preparative electrophoresis in the presence or absence of dissociating agents.

[0078] *Purification on DEAE-cellulose, which results in the isolation of immunochemically and physicochemically homogeneous J chain.* As a starting

material, the J chain-containing L chain fraction of polymeric IgA, S-IgA, or IgM, obtained by partial oxidative sulfitolysis and subsequent gel filtration on Sephadex® G-200 in 5 M guanidine-HCl can be used. Alternatively, S-sulfonated IgA or S-IGA can be directly applied on DEAE-cellulose. However, it is usually necessary to perform an additional separation using gel filtration on Sephadex® G-200 in 5 M guanidine-HCl to remove contaminating H chains.

[0079] Starting materials consist of the following reagents: L chain fraction of serum polymeric IgA or IgM, or colostral S-IgA; 0.01 M disodium phosphate in deionized 8 M urea solution and the same buffer with 0.7 M NaCl; DEAE-cellulose equilibrated in 0.01 M disodium phosphate containing 8 M urea; Sephadex® G-25 column in 1% NH_4HCO_3 solution.

[0080] Lyophilized L chain fraction is dissolved in 0.01 M disodium phosphate in 8 M urea, and applied on a DEAE-cellulose column equilibrated in the same phosphate solution. The column is thoroughly washed with this buffer. Absorbed proteins are eluted with a linear gradient of 0.01 M disodium phosphate in 8 M urea and 0.01 M disodium phosphate with 0.7 M NaCl. Two fractions are obtained, the later fraction containing J chain.

[0081] The J chain-containing fraction is desalted on a Sephadex® G-25 column in 1% NH_4HCO_3 adjusted to neutrality by bubbling with CO_2 . The purity of J chain can be assessed by alkaline-urea gel-electrophoresis or immunoelectrophoresis with anti- L, H, and J chain reagents.

B. Direct Synthesis of TM Polypeptides

[0082] Manual syntheses are performed with BOC-L-amino acids purchased from Biosearch-Milligen (Bedford, MA). Machine-assisted syntheses are performed with BOC-L-amino acids from Peptide Institute (Osaka, Japan) and Peptides International (Louisville, KY). BOC-D-amino acids are from Peptide Institute. BOC-L-His(DNP) and BOC-L-Aba are from Bachem Bioscience (Philadelphia, PA). Boc-amino acid-(4-carboxamidomethyl)-benzyl-ester-copoly(styrene-divinylbenzene)resins [Boc-amino acid-OCH₂-Pam-resins] are obtained from Applied Biosystems (Foster City, CA) and 4-methylbenzhydrylamine (4MeBHA) resin is from Peninsula Laboratories, Inc.

(Belmont, CA). Diisopropylcarbodiimide (DIC) is from Aldrich, and 2-(1H-benzotriazol-t-yl)-1,1,3,3-tetramethyluroniumhexafluorophosphate (HBTU) is obtained from Richelieu Biotechnologies (Quebec, Canada). For manual syntheses NN-diisopropylethylamine (DIEA), NN-dimethylformamide (DMF), dichloromethane (DCM) (all peptide synthesis grade) and 1-hydroxybenzotriazole (HOBt) are purchased from Auspep (Melbourne, Australia). For machine-assisted syntheses, DIEA and DCM are from ABI, and DMF is from Auspep. Trifluoroacetic acid (TFA) is from Halocarbon (New Jersey). Acetonitrile (HPLC grade) is obtained from Waters Millipore (Milford, MA). HF is purchased from Mallinckrodt (St. Louis, MO). Other reagents and solvents are ACS analytical reagent grade. Screw-cap glass peptide synthesis reaction vessels (20 mL) with a # 2 sintered glass filter frit are obtained from Embel Scientific Glassware (Queensland, Australia). A shaker for manual solid phase peptide synthesis is obtained from Milligen (Bedford, MA). An all-Kel F apparatus (Toho; from Peptide Institute, Osaka) is used for HF cleavage. Argon, helium and nitrogen (all ultrapure grade) are from Parsons (San Diego, CA).

[0083] *Chain assembly.* Syntheses are carried out on Boc-amino acid-OCH₂-Pam-resins, or on 4-MeBHA-resin. Boc amino acids are used with the following side chain protection: Arg(Tos); Asp(OBzl) (manual synthesis) and Asp(OcHxl); Cys(Bzl) (machine-assisted synthesis); Asn, unprotected (manual synthesis) and Asn(Xan) (machine-assisted synthesis); Glu(OcHxl); His(DNP); Lys(2CIZ); Thr(Bzl); Trp(InFormyl); and Tyr(BrZ). Gln and Met are used side chain unprotected.

[0084] *Manual protocol.* Syntheses are carried out on a 0.2 mmol scale. The Na⁺-Boc group is removed by treatment with 100 % TFA for 2 x 1 minute followed by a 30 second flow with DMF. Boc amino acids (0.8 mmol) are coupled, without prior neutralization of the peptide-resin salt, as active esters preformed in DMF with either HOBt/DIC (30 minute activation), or HBTU/ DIEA (2 minute activation) as activating agents. For couplings with active esters formed by HOBt/DIC, neutralization is performed *in situ* by adding 1.5 equivalents of DIEA relative to the amount of TFA O⁻·⁺NH₃-peptide-resin salt to the activated Boc-amino acid/resin mixture. For couplings with active esters formed from HBTU/DIEA, an additional 2 equivalents DIEA relative

to the amount of TFA $O^{-+}NH_3$ -peptide-resin salt are added to the activation mixture. Coupling times are 10 minutes throughout without any double coupling. Samples (3-5 mg) of peptide-resin are removed after the coupling step for determination of residual free α -amino groups by the quantitative ninhydrin method. Coupling yields are typically > 99.9%. All operations are performed manually in a 20 mL glass reaction vessel with a Teflon-lined screw cap. The peptide-resin is agitated by gentle inversion on a shaker during the NII-deprotection and coupling steps.

[0085] *Deprotection and cleavage.* His(DNP)-containing peptides are treated with a solution of 20% mercaptoethanol/10% DIEA in DMF for 2 x 30 minutes in order to remove the DNP group, prior to the removal of the Boc group. The N^{α} -Boc group is removed from the peptide-resin by treatment with neat TFA (2 x 1 minute). The peptide-resin is washed with DMF and neutralized with 10% DIEA in DMF (1 x 1 minute). After removal of the DNP and Boc group, the peptide-resin is treated with a solution of ethanolamine in water/DMF for 2 x 30 minutes to remove the formyl group of Trp(InFormyl).

[0086] The partially-deprotected peptide-resin is dried under reduced pressure after washing with DMF and DCM. Side chain protecting groups are removed and simultaneously the peptide is cleaved from the resin by treatment with HF/p-cresol (9:1 v/v, 0°C, 1 hour) or HF/p-cresol/thiocresol (9:0.5:0.5 by vol., 0°C, 1 hour). The HF is removed under reduced pressure at 0°C and the crude peptide precipitated and washed with ice-cold diethyl ether, then dissolved in either 20% or 50% aqueous acetic acid, diluted with H₂O and lyophilized.

[0087] *Peptide joining.* Joining of peptide segments of TM produced by the synthetic procedures described above is carried out by chemical ligation of unprotected peptides. These procedures can yield a free sulfhydryl at the junctional peptide bond or can yield a disulfide bond. Alternatively, cysteine residues at specified positions are replaced by L-aminobutyric acid.

[0088] In one procedure, the synthetic segment peptide 1, which contains a thioester at the α -carboxyl group, undergoes nucleophilic attack by the side chain of the Cys residue at the amino terminal of peptide 2. The initial thioester ligation product

undergoes rapid intramolecular reaction because of the favorable geometric arrangement (involving a five-membered ring) of the α -amino group of peptide 2, to yield a product with the native peptide bond of a cysteine moiety at the ligation site. Both reacting peptide segments are in completely unprotected form, and the target peptide is obtained in final form without further manipulation. Additional cysteine residues in either peptide 1 or peptide 2 are left in their reduced state.

[0089] In another procedure, unprotected peptide segments containing terminal cysteine moieties are ligated via nucleophilic attack of a deprotonated α -thioacid group on a bromoacetyl moiety to form two monomers each with a short N- or C-terminal extension containing an unprotected sulfhydryl group. After derivatization of the cysteamine-containing monomer with 2,2'-dipyridyl disulfide, the desired disulfide-linked heterodimer is formed by thiolysis of the S-(2-pyridylisulphenyl)cysteamine derivative.

[0090] These procedures are used to derive a variety of TM configurations, such as the representative TMs provided below:

Table I
Direct Synthesis of TM Polypeptides

Segments	Chemistry	Strategy to form Closed Covalent Loop	Representative Attachment Sites
A. TM Core			
1. 12-71	N-cysteine C-glyNH ₂ CH ₂ CH ₂ SH	71 to 91 via disulfide linker; 12 to 101 via	sulfhydryls at 14 and 68
2. 91-101	N-glyCOCH ₂ SH C-cysteine	Renaturation and Oxidation to disulfide	
B. TM Core			
1. 31-71	N-BrCH ₂ CO C-glyNH ₂ CH ₂ CH ₂ SH	71 to 91 via disulfide linker; 30 to 31 via	sulfhydryls at 14 and 68
2. 91-30	N-glyCOCH ₂ SH C-thioacid	Thioester; 12 to 101 Exists as peptide Bonds (serine-glycine- Alanine in place of cys	

Segments	Chemistry	Strategy to form Closed Covalent Loop (to cys disulfide)	Representative Attachment Sites
C. TM Extended			
1. 1-67	N - NH_3^+ C - thioester	67 to 68 via native chemical ligation; 118	sulphydryls at 14 and 68
2. 68-118	N - cysteine C - thioacid	to 119 via thioester; 71 to 91, 12 to 101	
3. 119-136	N - BrCH_2CO C - COO^-	and 108 to 133 via renaturation and oxidation to form disulfides	
D. TM Core Variat			
1. serine 68 serine 14	Same as A or B "	Same as A or B "	sulphydryl at 14; sulphydryl at 68;
2. serine 68 + serine 14	"	"	free amines or free carboxyls
E. TM Extended V.			
1. 1-70	N - NH_3^+ C - thioester	67 to 68 via native chemical ligation; 118	reactive group at 1; for attachment of
71-118	N - cysteine C - thioacid	to 119 via thioester; 71 to 91, 12 to 101	bromoacetylated peptide linker
119-136	N - BrCH_2CO C - $\text{glyNH}_2\text{CH}_2\text{CH}_2\text{SH}$	and 108 to 133 via renaturation and oxidation to form disulfides; serines at 14 and 68	
2. 1-70	N - BrCH_2CO C - thioester	67 to 68 via native chemical ligation; 118	reactive group at 1 for attachment of
71-118	N - cysteine C - thioacid	to 119 via thioester; 71-91, 12 to 101 and	sulphydryl peptide linker

Segments	Chemistry	Strategy to form	Representative
119-136	N - BrCH ₂ CO C - COO ⁻	Closed Covalent Loop and 108 to 133 via renaturation and oxidation to form disulfides; serines at 14 and 68	Attachment Sites

"Extended" = a TM comprising the 88 residues of the core, plus an additional 48 residues derived from native J chain; "Core" = residues 12-101 of native J chain; residues are indicated according to the numbering in Figure 1

C. Synthesis and Expression of DNAs Encoding TM

[0091] DNA chains can be synthesized by the phosphoramidite method, which is well known in the art, whereby individual building block nucleotides are assembled to create a desired sequence. Automated DNA synthesis of TM DNAs involves the synthesis and joining of individual oligonucleotides encoding portions of TMs to form the entire desired sequence. Synthetic DNA can be purchased from a number of commercial sources.

[0092] Transgenic expression of TMs requires ligation of the synthetic coding DNA into a vector for transformation of the appropriate organism. Techniques of ligation into vectors are well described in the literature. For example, in order to enable the introduction and expression of TMs in insect cells, the synthetic TM DNA is ligated into the pFastBac1 vector (GibcoBRL) to form the pFastBac1-TM recombinant. The recombinant vector is then used to transform *E. coli* bacteria containing a helper plasmid and a baculovirus shuttle vector. High molecular weight shuttle vector DNA containing transposed TM coding sequences is then isolated and used for transfection of insect cells. Recombinant baculovirus are harvested from transfected cells and used for subsequent infection of insect cell cultures for protein expression.

[0093] A TM can be synthesized by expressing in cells a DNA molecule encoding the TM. The DNA can be included in an extrachromosomal DNA element or integrated into the chromosomal DNA of the cell expressing the TM. Alternatively, the TM DNA can be included as part of the genome of a DNA or RNA virus which directs the

expression of the TM in the cell in which it is resident. An example of a DNA sequence encoding TM is shown in SEQ ID NO:7. This DNA sequence and the amino acid sequence encoded by this TM DNA are also shown in Table II.

[0094] One method of synthesizing such a TM gene involves the sequential assembly of oligonucleotides encoding portions of the TM gene into a complete TM gene. The final assembly of the TM gene can occur in a DNA expression vector suitable for expression in a cellular system, or the TM gene can be constructed in a convenient cloning vector and subsequently moved into a DNA expression vector suitable for expression in a cellular system. An advantage of the sequential assembly of the TM gene from partial coding regions is the ability to generate modified versions of the TM gene by using alternative sequences for one or more of its individual portions during the assembly of the TM gene. Alternatively, the restriction endonuclease sites encoded in the TM gene can be used after the assembly of part or all of the TM gene to replace portions of the TM coding sequence to generate alternative TM coding sequences, as described by Sambrook et al., *Molecular Cloning: A Laboratory Manual*, 2d ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, NY, 1989.. The TM gene can be divided into several partial coding regions: D1 encoding amino acids approximately -2 to 20; C2 encoding amino acids approximately 19 to 66; L3 encoding amino acids approximately 65 to 102; and T4 encoding amino acids approximately 102 to 142 of the sequence recited in Table II. Unless otherwise indicated, references to amino acid residue numbers in the following section are to the residue indicated in Table II.

[0095] *Assembly of a synthetic gene encoding TM Core polypeptide.* A TM Core gene sequence may be defined by the combination of C2, D1.1 (a modified version of D1, and L3Δ (a modified version of L3). One version of TM Core may be generated from the oligonucleotides 1.1, 2.1, 3, 4, 5, 6, 7, 8, 9L3Δ and 10L3Δ (SEQ ID NOs:48, 49, 54-56, 58, 60, 61, 63, 64) listed in Table III and encodes a polypeptide of sequence:

DQKCKCARITSRIIRSSDPNEDIVERNIRIIVPLNNRENISDPTSPLRTRFV
YHLS DLCKKDEDSATETC (Table VIII and SEQ ID NO:18).

A gene containing D1.1, C2, and L3Δ or alternate coding sequences that differ only in conservative substitutions or modifications is a complete TM Core gene.

[0096] Assembly of C2. In one example, *de novo* synthesis of a TM gene (including the TM core) may be initiated by assembly of a partial gene, called C2, encoding amino acids 19-66 of the TM. The sequence of C2 DNA and the peptide sequence encoded by the C2 DNA are shown in Table IV and SEQ ID NO:9. C2 is generated by annealing oligonucleotides 3, 4, 5, 6, 7 and 8 of Table III (SEQ ID NOs:54-56, 58, 60, 61) into a DNA fragment encoding approximately 48 amino acids of the TM Core polypeptide. Oligonucleotide pairs 3&4, 5&6, and 7&8 are first annealed pairwise into overlapping DNA duplexes, and the 3 double stranded DNAs are then annealed together to form a double stranded DNA complex composed of the 6 individual oligonucleotides. Oligonucleotides 1 and 8 have overhanging unpaired ends compatible with the unpaired ends of DNA restricted with the enzymes Xba I and Bgl II, respectively. C2 is annealed into the vector pMelBac XP, at the Xba I and Bgl II restriction endonuclease sites of the multiple cloning region and the DNA fragments enzymatically ligated to form the vector pTMC (Method 1).

[0097] Method 1: Synthesis of C2 DNA from oligonucleotides and insertion into pMelBac XP to form pTMC. Individual oligonucleotides 3, 4, 5, 6, 7, and 8 (SEQ ID NOs:54-56, 58, 60, 61) are separately dissolved in TE buffer (Sambrook et al., *Molecular Cloning: A Laboratory Manual*, 2d ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, NY, 1989) at a concentration of 1mM (1 nanomole/microliter). Two nanomoles of each oligonucleotide are combined with the same amount of its pair (*e.g.*, (3&4), (5&6) or (7&8)) in 10µL of annealing buffer (10 mM Tris pH 8.0, 100 mM NaCl, 1 mM EDTA) in a microcentrifuge tube, and the tubes immersed in 50mL boiling water for 5 minutes. The entire boiling water bath, including microcentrifuge tubes, is then removed from the heat source and allowed to cool to room temperature (approximately 24 °C), allowing the oligonucleotides to form base-paired DNA duplexes. After incubating for 30 minutes at room temperature, 1 nanomole of each oligonucleotide pairs, ([*e.g.*, (3&4), (5&6), and (7&8)], are combined in a single microcentrifuge tube. The tube containing these DNA duplexes is incubated at 55 °C for 15 minutes in a heating block, removed from the heating block and equilibrated to room temperature, allowing overlapping complementary regions of the DNA duplexes to anneal, forming a DNA duplex encoding the partial TM DNA C2.

[0098] One nanomole of the oligonucleotide duplex is then mixed with 0.1 picomole of pMelBac XP which has previously been restricted with endonucleases Xba I and Bgl II. pMelBac XP is a DNA vector for cloning and subsequent expression in insect cells of synthetic TM genes, derived from pMelBac B (Invitrogen, San Diego, CA). The sequence of the secretion signal and multiple cloning site is (SEQ ID NO:42 and SEQ ID NO:43):

```
met lys phe leu val asn val ala leu val phe met val tyr
atg aaa ttc tta gtc aac gtt gcc ctt ttt atg gtc gta tac

ile ser tyr ile tyr ala asp pro ser ser ser ala
att tct tac atc tat gcg gat ccg agc tcg agt gct cta ga

tct gca gct ggt acc atg gaa ttc gaa gct tgg agt cga ctc

tgc tga
```

[0099] The mixture of vector DNA and synthetic gene fragment is then heated to 35 °C for 15 minutes, then 1/10 volume of Ligation Stock Buffer is added, DNA ligase is added and the reaction mixture incubated at 12 °C for 12 hours to ligate the phosphodiester bonds among oligonucleotides and vector DNA, as described in Sambrook et al., *Molecular Cloning: A Laboratory Manual*, 2d ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, NY, 1989. DNA is then used for transfection of competent *E. coli* cells by standard methods (see Sambrook et al., *supra*). Plasmid DNA is isolated from these cells and is evaluated by restriction endonuclease digestion or DNA sequencing to evaluate the success of synthetic DNA assembly and cloning. The resulting plasmid, pTMC is then used as a framework for successive addition of synthetic TM sequences.

[0100] Assembly of D1.1 and insertion into the TM synthetic gene. A fragment of the TM DNA proximal to C2, called D1.1, encodes amino acids 9 to 20 of the TM. The DNA sequence and primary amino acid peptide sequence of D1.1 are shown in Table V, SEQ ID NO:10 and SEQ ID NO:20. D1.1 encodes the proximal amino acids of the TM Core polypeptide (residues 12 to 20) as well as a short peptide of three amino acids which serve to join the TM Core with a leader peptide (appropriate for the expression system employed for synthesis of TM). D1.1 is generated by

annealing oligonucleotides 1.1 (SEQ ID NO:48) and 2.1 (SEQ ID NO:51) into a DNA duplex as described in Method 1. Oligonucleotides 1.1 and 2.1 have overhanging unpaired ends compatible with the unpaired ends of BamHI (or Bgl II) and Xba I, respectively. D1.1 is annealed into pTMC at the BamHI and Xba I restriction endonuclease sites of the multiple cloning region and the DNA fragments enzymatically ligated, in a manner similar to that described in Method 1 for pTMC, to form the vector pTMD1.1C.

[0101] Assembly of L3 Δ and insertion into the TM synthetic gene. A fragment of the TM DNA distal to C2, called L3 Δ , encodes a contiguous polypeptide of amino acids 66-70 and 92-101 of the TM provided in Table II. The DNA sequence and peptide sequence of L3 are shown in Table VI, SEQ ID NO:11 and SEQ ID NO:21. L3 Δ is generated by annealing oligonucleotides 9L3 Δ and 10L3 Δ into a DNA duplex as described in Method 1 to generate the distal portion of the TM Core DNA encoding approximately 14 amino acids. Oligonucleotides 9L3 Δ and 10L3 Δ have overhanging unpaired ends compatible with the unpaired ends of Bgl II and EcoRI, respectively. L3 Δ is ligated into the vector pTMD1.1C at the Bgl II and EcoRI restriction endonuclease sites and the DNA fragments enzymatically ligated, in a manner similar to that described in Method 1 for pTMC, to form the vector pTMCore.

[0102] A TM may also be synthesized as described above, except that L3 (discussed below) is used in place of L3 Δ . The sequence of such a TM is provided in Table IX and SEQ ID NO:13.

[0103] Assembly of a synthetic gene encoding a full length TM polypeptide. A full length TM gene sequence may be defined by the combination of D1, C2, L3 and T4. One example of a full length TM gene (SEQ ID NO:7) is generated from the oligonucleotides 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16 listed in Table III (SEQ ID NOs:46, 47, 54-56, 58, 60-62 and 73-79). A gene containing D1, C2, L3, and T4 or coding sequences that differ only in conservative substitutions or modifications is a full length TM gene.

[0104] Assembly of D1 and insertion into the TM synthetic gene. A fragment of the TM DNA proximal to C2, called D1, encodes amino acids -2 to 20 of the TM. The DNA sequence and peptide sequence of D1 are shown in Table V.A, SEQ ID

NO:15 and SEQ ID NO:25. D1 encodes the proximal amino acids of the TM Core polypeptide (residues 12 to 20) as well as a peptide of 13 amino acids which serves to join the TM Core with a leader peptide (appropriate for the expression system employed for synthesis of TM). D1 is generated by annealing oligonucleotides 1 and 2 (Table III; SEQ ID NO:46 and SEQ ID NO:47, respectively). Oligonucleotides 1 and 2 have overhanging unpaired ends compatible with the unpaired ends of BamHI (or Bgl II) and Xba I, respectively. D1 is annealed into pTMC at the BamHI and Xba I restriction endonuclease sites of the multiple cloning region and the DNA fragments enzymatically ligated, in a manner similar to that described in Method 1 for pTMC, to form the vector pTMDC.

[0105] Assembly of L3 and insertion into the TM synthetic gene. A fragment of the TM DNA distal to C2, called L3, encodes amino acids 66-101 of TM. The DNA sequence and peptide sequence of L3 are shown in Table VI.A, SEQ ID NO:15 and SEQ ID NO:25. L3 is generated by annealing oligonucleotides 9, 10, 11, and 12 (Table III; SEQ ID NOs:62, 73-75) into a DNA duplex to generate the distal portion of the TM Core DNA encoding approximately 35 amino acids. Oligonucleotide pairs 9&10 and 11&12 are first annealed together to form a double stranded DNA complex composed of the 4 individual oligonucleotides. Oligonucleotides 9 and 12 have overhanging unpaired ends compatible with the unpaired ends of Bgl II and Pst I, respectively. L3 is annealed into the vector pTMDC at the Bgl II and PstI restriction endonuclease sites and the DNA fragments enzymatically ligated, in a manner similar to that described in Method 1 for pTMC, to form the vector pTMDCL.

[0106] Assembly of T4 and insertion into the TM synthetic gene. A fragment of the TM DNA distal to L3, called T4, encodes amino acids 102-141 of the TM. The DNA sequence and peptide sequence of L4 are shown in Table VII, SEQ ID NO:12 and SEQ ID NO:22. L3 is generated by annealing oligonucleotides 13, 14, 15, and 16 (Table III; SEQ ID NOs:76-79) into a DNA fragment which is the distal portion of the full length TM DNA encoding approximately 36 amino acids. Oligonucleotide pairs 13&14 and 15&16 are first annealed pairwise into overlapping DNA duplexes, and the two double stranded DNAs are subsequently annealed together to form a double stranded DNA complex composed of the 4 individual oligonucleotides.

Oligonucleotides 13 and 16 have overhanging unpaired ends compatible with the unpaired ends of Pst I and EcoRI, respectively. T4 is annealed into the vector pTMDCL at the Pst I and Eco RI restriction endonuclease sites and the DNA fragments enzymatically ligated, in a manner similar to that described in Method 1 for pTMC, to form the vector pTM.

[0107] *Assembly of synthetic genes encoding modified TM polypeptides.* Other versions of TM genes, in which the peptide sequence is altered from the full length TM or TM Core, can be synthesized by using alternative oligonucleotides to 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, or 16 listed in Table III (SEQ ID NOs:46, 47, 54-56, 58, 60-62, 73-79). These alternative oligonucleotides can be employed during synthesis of a partial TM gene, or can be used to generate DNA fragments which can replace coding sequences in an assembled TM gene or TM gene fragment by removing DNA fragments with restriction endonucleases, and replacing the original sequence with an alternative coding sequence. In addition, DNA sequences encoding polypeptides unrelated to TM can be inserted into the TM coding sequences at various positions.

[0108] Assembly of a synthetic gene encoding an aglycosylated TM polypeptide. In one example oligonucleotides 5 and 6 are replaced during the assembly of C2 with oligonucleotides 5.1dg (SEQ ID NO:57) and 6.1dg (SEQ ID NO:59), shown in Table III, to form a new fragment called C2Δglyco. This oligonucleotide substitution results in an altered C2 DNA sequence so that the asparagine encoded at residue 48 is changed to a histidine. With the exception of the oligonucleotides 5.1dg and 6.1dg, C2Δglyco is created in the same manner as C2. C2Δglyco can be used in the synthesis of a variety TM sequences in a manner similar to that described for TM Core and full length TM sequences.

[0109] Assembly of a synthetic gene encoding a TM polypeptide with a modified L3 domain. In another example, TM amino acid residues 71-91 are replaced with the three amino acid peptide: ser-asp-ile. In this example oligonucleotides 9.2Δ3 (SEQ ID NO:67) and 10.2Δ3 (SEQ ID NO:68), shown in Table III, are first annealed into a DNA duplex and subsequently annealed into the vector pTMDC at the Bgl II and Eco RI restriction endonuclease sites. The annealed DNA fragments are then enzymatically ligated to form the vector pTMLΔ3.

[0110] Assembly of synthetic genes encoding a TM polypeptide with cysteine residue 68 replaced. In other examples, the oligonucleotide pairs 9.3 Δ 3ser&10.3 Δ 3ser (SEQ ID NO:69 and SEQ ID NO:70) or 9.3 Δ 3val&10.3 Δ 3val (SEQ ID NO:71 and SEQ ID NO:72) are annealed into DNA duplexes and digested with the enzyme ClaI and subsequently annealed into pTML Δ 3 which has been digested with restriction enzymes ClaI and PstI. These two oligonucleotide pairs, when inserted into pTM1 Δ 3, result in a TM Δ 3 molecule with the cysteine at position 68 replaced by serine or valine, respectively.

[0111] Assembly of synthetic genes encoding a TM polypeptide with cysteine residue 14 replaced. In another example the oligonucleotide pairs 1.2ser&2.2ser (SEQ ID NO:50 and SEQ ID NO:51) or 1.2val&2.2val (SEQ ID NO:52 and SEQ ID NO:53) can be annealed to generate an alternative domain to D1 with the cysteine residue 14 replaced with serine or valine, respectively. These oligonucleotide pairs are then annealed, in the same manner as described above for D1, into pTMC at the BamHI and Xba I restriction endonuclease sites of the multiple cloning region and the DNA fragments enzymatically ligated to form alternatives to the vector pTMD1C.

[0112] Assembly of a synthetic gene encoding a TM core polypeptide containing an endomembrane retention signal. In a further example TM core is synthesized with the endomembrane retention signal KDEL (SEQ ID NO:44) as the carboxyterminal amino acid residues. In this example oligonucleotides 9L3 Δ KDEL (SEQ ID NO:65) and 10L3 Δ KDEL (SEQ ID NO:66) are substituted for oligonucleotides 9L3 Δ and 10L3 Δ during synthesis of TM core described above to form the vector pTML Δ 3KDEL.

[0113] Assembly of a synthetic gene encoding a full length TM polypeptide containing an endomembrane retention signal. In another example TM is synthesized with the endomembrane retention signal KDEL (SEQ ID NO:44) as the carboxyterminal amino acid residues. In this example oligonucleotides 15KDEL (SEQ ID NO:80) and 16KDEL (SEQ ID NO:81) are substituted for oligonucleotides 15 and 16 as described above for synthesis of T4. The substitution of these two oligonucleotides results in the formation of coding sequence T4KDEL which when

substituted for T4 in the above described synthesis of pTM results in the formation of the vector pTMKDEL.

[0114] Assembly of a synthetic gene encoding a TM polypeptide containing an additional amino terminal sequence. In one example a TM gene is synthesized with the polyimmunoglobulin receptor sequence from residues 585-600 (AIQDPRLFAEEKAVAD; SEQ ID NO:45) included as part of the amino terminal domain. The oligonucleotides P1 (SEQ ID NO:82) and P2 (SEQ ID NO:83) encode this polyimmunoglobulin receptor sequence and amino acid residues of D1. P1 and P2 have overhanging unpaired ends compatible with the unpaired ends of Bam HI and XbaI, respectively. The oligonucleotides P1 and P2 are annealed into a DNA duplex which can be used in place of D1.1 or D1 in the synthesis of a TM expression vectors as described above.

[0115] Assembly of a synthetic gene encoding a TM polypeptide in which a component of TM is replaced by another peptide domain, TpS2. In this Example, a TM gene is synthesized with a peptide replacing TM Domains 4, 5 and 6. This peptide, referred to as TpS2, encodes an enterokinase cleavable peptide between the terminal residue of Domain 2 and the coding sequence for the trefoil peptide pS2 (as reported in Suemori et al., *Proc. Natl. Acad. Sci.* 88:11017-11021, 1991). The DNA sequence and peptide sequence of TpS2 are shown in Table X. TpS2 is generated by annealing oligonucleotides Tp1, Tp2, Tp3, Tp4, Tp5 and Tp6 (Table III; SEQ ID NOs:87-92) into a DNA fragment which encodes approximately 64 amino acids. Oligonucleotide pairs Tp1 & Tp2, Tp3 & Tp4 and Tp5 & Tp6 are first annealed pairwise into overlapping DNA duplexes, and the two double stranded DNAs are subsequently annealed together to form a double stranded DNA complex composed of the 6 individual oligonucleotides. Oligonucleotides Tp1 and Tp6 have overhanging unpaired ends compatible with the unpaired ends of PstI and EcoRI restriction sites, respectively. TpS2 is annealed into the vector pTMDCL at the PstI and EcoRI restriction endonuclease sites and the DNA fragments enzymatically ligated, in a manner similar to that described in Method 1 for pTMC, to form a vector pTMpSp2, which encodes a TM with the trefoil peptide pS2 included as a replacement for TM Domains 4, 5 and 6.

D. Isolation and Expression of cDNA Encoding Human J chain

[0116] Two human small intestine cDNA libraries (Clontech Laboratories, Palo Alto CA; cat #HL1133a and dHL1133b) are screened using a synthetic DNA complementary to the 5' end of the human J chain messenger RNA. The probes are labeled with [³²P] using polynucleotide kinase in standard reactions. The library screening is performed as described by the manufacturer (Clontech). Hybridization is carried out according to Church and Gilbert, *Proc. Natl. Acad. Sci. USA* 81:1991-1995, 1984. After autoradiography, positive plaques are isolated and the phage are disrupted by boiling for 10 minutes. The cDNA inserts are amplified by PCR in a total volume of 50 µL containing standard PCR buffer, 25 pmoles of primers complementary to the 5' and 3' ends of the human J chain cDNA, 200 µM of each dNTP, and 1.0 unit of Taq polymerase. The DNA is denatured for 3 minutes at 94°C prior to 35 cycles of amplification. Each cycle consisted of 1 min at 94°C, 1 min at 62°C, and 1 min at 72°C. The PCR fragments are cloned into pUC19 and sequenced. Full length cDNA inserts are then subcloned into the appropriate insect expression vector (pMelBacXP) utilizing restriction sites placed in the two PCR primers.

TABLE II
DNA Sequence and Primary Amino Acid Structure of a Representative
Full Length TM Molecule

-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
asp	gln	glu	asp	glu	arg	ile	val	leu	val	asp	asn	lys	cys	lys	cys	ala	arg
gat	cag	gaa	gat	gaa	cgt	att	ggt	ctg	ggt	gac	aac	aag	tgc	aag	tgt	gct	cgt
cta	gtc	ctt	cta	ctt	gca	taa	caa	gac	caa	ctg	ttg	ttc	acg	ttc	aca	cga	gca
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
ile	thr	ser	arg	ile	ile	arg	ser	ser	glu	asp	pro	asn	glu	asp	ile	val	glu
att	act	tct	aga	atc	atc	cgt	agc	tca	gag	gac	cca	aat	gaa	gat	ata	gtc	gaa
taa	tga	aga	tct	tag	tag	gca	tcg	agt	ctc	ctg	ggg	tta	ctt	cta	tat	cag	ctt
35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
arg	asn	ile	arg	ile	ile	val	pro	leu	asn	asn	arg	glu	asn	ile	ser	asp	pro
cgt	aac	atc	cgt	atc	atc	gtc	cca	ctg	aat	aac	cgg	gag	aat	atc	tca	gat	cct
gca	ttg	tag	gca	tag	tag	cag	ggg	gac	tta	ttg	gcc	ctc	tta	tag	agt	cta	gga
53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
thr	ser	pro	leu	arg	thr	arg	phe	val	tyr	his	leu	ser	asp	leu	cys	lys	lys
aca	agt	ccg	ttg	cgc	aca	cgc	ttc	gta	tac	cac	ctg	tca	gat	ctg	tgt	aag	aag
tgt	tca	ggc	aac	gcg	tgt	gcg	aag	cat	atg	gtg	gac	agt	cta	gac	aca	ttc	ttc
71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
cys	asp	pro	thr	glu	val	glu	leu	asp	asn	gln	ile	val	thr	ala	thr	gln	ser
tgt	gat	cca	aca	gag	gta	gag	ctg	gac	aat	cag	ata	gtc	act	gcg	act	caa	agc
aca	cta	ggg	tgt	ctc	cat	ctc	gac	ctg	tta	gtc	tat	cag	tga	cgc	tga	ggt	tcg
89	90	91	92	93	94	95	96	97	99	100	101	102	103	104	109	110	111
asn	ile	cys	asp	glu	asp	ser	ala	thr	glu	thr	cys	ser	thr	tyr	asp	arg	asn
aac	att	tgc	gat	gag	gac	agc	gct	aca	gaa	acc	tgc	agc	acc	tac	gat	agg	aac
ttg	taa	acg	cta	ctc	ctg	tcg	cga	tgt	ctt	tggt	acg	tcg	tggt	atg	cta	tcc	ttg
112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129
lys	cys	tyr	thr	ala	val	val	pro	leu	val	tyr	gly	gly	glu	thr	lys	met	val
aaa	tgc	tac	acg	gcc	gtg	ggt	ccg	ctc	gtg	tat	ggg	gga	gag	aca	aaa	atg	gtg
ttt	acg	atg	tgc	cgg	cac	caa	ggc	gag	cac	ata	cca	cct	ctc	tgt	ttt	tac	cac
130	131	132	133	134	135	136	137	138	139	140	141						
glu	thr	ala	leu	thr	pro	asp	ala	cys	tyr	pro	asp	OPA					
gaa	act	gcc	ctt	acg	ccc	gat	gca	tgc	tat	ccg	gac	tga	attc				
ctt	tga	cgg	gaa	tgc	ggg	cta	cgt	acg	ata	ggc	ctg	act	taag				

TABLE III
Oligonucleotides for Construction of Representative Partial TM Genes

<u>OLIGO</u>	<u>SEQUENCE</u>
1:	gat cag gaa gat gaa cgt att gtt ctg gtt gac aac aag tgc aag tgt gct cgt att act t
2:	cta gaa gta ata cga gca cac ttg cac ttg ttg tca acc aga aca ata cgt tca tct tcc t
1.1:	gat cag aag tgc aag tgt gct cgt att act t
2.1:	ct aga agt aat acg agc aca ctt gca ctt ct
1.2ser:	gat cag gaa gat gaa cgt att gtt ctg gtt gac aac aag tgc aag tcc gct cgt att act t
2.2ser:	cta gaa gta ata cga gcg gac ttg cac ttg ttg tca acc aga aca ata cgt tca tct tcc t
1.2val:	gat cag gaa gat gaa cgt att gtt ctg gtt gac aac aag tgc aag gtt gct cgt att act t
2.2val:	cta gaa gta ata cga gca acc ttg cac ttg ttg tca acc aga aca ata cgt tca tct tcc t
3:	cta gaa tca tcc gta gct cag agg acc caa atg aag ata tag tcg aa
4	gat acg gat gtt acg ttc gac tat atc ttc att tgg gtc ctc tga gct acg gat gat t
5:	cgt aac atc cgt atc atc gtc cca ctg aat aac cgg gag aat atc tca g

5.1dg: cgt aac atc cgt atc atc gtc cca ctg aat aac cgg gag cac atc
tca g

6: acg gac ttg tag gat ctg aga tat tct ccc ggt tat tca gtg gga
cga t

6.1dg: acg gac ttg tag gat ctg aga tgt gct ccc ggt tat tca gtg gga
cga t

7: atc cta caa gtc cgt tgc gca cac gct tcg tat acc acc tgt ca

8: gat ctg aca ggt ggt ata cga agc gtg tgc gca

9: gat ctg tgt aag aag tgt gat cca aca gag gta gag ctg gac aat
cag ata gtc act gca

9L3Δ: gat ctg tgt aag aag gat gag gac agc gct aca gaa acc tgc tg

10L3Δ: aat tca gca ggt ttc tgt agc gct gtc ctc atc ctt ctt aca ca

9L3ΔKDEL: gat ctg tgt aag aag gat gag gac agc gct aca gaa acc tgc tac
gag aag gat gag ctg tg

10L3ΔKDEL: aat tca cag ctc atc ctt cgc gtc gca ggt ttc tgt agc gct gtc
ctc atc ctt ctt aca ca

9.2Δ3: gat ctg tgt aag aag tct gat atc gat gaa gat tcc gct aca gaa
acc tgc agc aca tg

10.2Δ3: aat tca tgt gct gca ggt ttc tgt agc gga atc ttc atc gat atc
aga ctt ctt aca ca

9.3Δ3/ser68: gat ctg tct aag aag tct gat atc gat gaa gat tac aga ttc ttc
aga cta tag cta ctt cta a

10.3Δ3/ser68: aat ctt cat cga tat cag act tct tag aca

9.3Δ3/val68: gat ctg gtt aag aag tct gat atc gat gaa gat tac caa ttc ttc
aga cta tag cta ctt cta a

10.3Δ3/val68: aat ctt cat cga tat cag act tct taa cca

10: att gtc cag ctc tac ctc tgt tgg atc aca ctt ctt aca ca

11: act caa agc aac att tgc gat gag gac agc gct aca gaa acc tgc a

12: ggt ttc tgt agc gct ctg ctc atc gca aat gtt gct ttg agt cgc
agt gac tat ctg

13: gc acc tac gat agg aac aaa tgc tac acg gcc gtg gtt ccg ctc
gtg tat ggt gga gag

14: gag cgg aac cac ggc cgt gta gca ttt gtt cct atc gta ggt gct
gca

15: aca aaa atg gtg gaa act gcc ctt acg ccc gat gca tgc tat ccg
gac tg

16: aat tca gtc cgg ata gca tgc atc ggg cgt aag ggc agt ttc cac
cat ttt tgt ctc tcc acc ata cac

15KDEL: aca aaa atg gtg gaa act gcc ctt acg ccc gat gca tgc tat ccg
gac aag gat gaa ttg tg

16KDEL: aat tca caa ttc atc ctt gtc cgg ata gca tgc atc ggg cgt aag
ggc agt ttc cac cat ttt tgt ctc tcc acc ata cac

P1: gat cag gtc gct gcc atc caa gac ccg agg ctg ttc gcc gaa gag
aag gcc gtc gct gac tcc aag tgc aag tgt gct cgt att act t

P2: ct aga agt aat acg agc aca ctt gca ctt gga gtc agc gac ggc
ctt ctc ttc ggc gaa cag cct cgg gtc ttg gat ggc agc gac ct

Tp1: gc gat gac gac gat aag gcc caa acg gag acc tgt act gtt gcg cct cgt gaa
cgg caa aac tgc gga ttc ccg gaa

Tp2: gtt ttg ccg ttc acg agg cgc aac agt aca ggt ctc cgt ttg ggc ctt atc
gtc gtc atc gct tca

Tp3: gta aca ccc tct cag tgc gct aat aaa ggc tgc tgt ttt gat gac acg gta
cgg ggc gtt ccg tgg tgc ttc

Tp4: gcc ccg tac cgt gtc atc aaa aca gca gcc ttt att agc gca ctg aga ggg
tgt tac ttc cgg gaa tcc gca

Tp5: tac ccc aat aca att gac gtt ccg cct gaa gaa gag tgc gag ccg taa g

Tp6: aattc tta cgg ctc gca ctc ttc ttc agg cgg caa gtc aat tgt att ggg
gta gaa gca cca cgg aac

Peptide and cDNA sequence of Domain C2 of TM (TM aa residues 19-65)

[illegible][illegible]

DNA sequence and primary amino acid structure of Domain D1.1 of TM
(TM aa residues 9-20)

[illegible]

DNA sequence and primary amino acid structure of Domain D1 of TM
(TM aa residues -2-20)

```

-2  -1   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
asp gln glu asp glu arg ile val leu val asp asn lys cys lys cys ala
gat cag gaa gat gaa cgt att gtt ctg gtt gac aac aag tgc aag tgt gct
      tc ctt cta ctt gca taa caa gac caa ctg ttg ttc acg ttc aca cga

  16  17  18  19  20
arg ile thr ser arg
cgt att act t
gca taa tga aga tc

```

Peptide and DNA sequence of Domain L3Δ of TM (TM aa residues 66-70 and 92-101)

```

66  67  68  69  70  92  93  94  95  96  97  99 100 101
asp leu cys lys lys asp glu asp ser ala thr glu thr cys OPA
gat ctg tgt aag aag gat gaa gat tcc gct aca gaa acc tgc tg
      ac aca ttc ttc cta ctt ctc agg cga tgt ctt tgg acg act taa

```

TABLE VI.APeptide and DNA sequence of Domain L3 of TM (TM aa residues 66-101)

66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81
<i>asp</i>	<i>leu</i>	<i>cys</i>	<i>lys</i>	<i>lys</i>	<i>cys</i>	<i>asp</i>	<i>pro</i>	<i>thr</i>	<i>glu</i>	<i>val</i>	<i>glu</i>	<i>leu</i>	<i>asp</i>	<i>asn</i>	<i>gln</i>
gat	ctg	tgt	aag	aag	tgt	gat	cca	aca	gag	gta	gag	ctg	gac	aat	cag
cta	gac	aca	ttc	ttc	aca	cta	ggg	tgt	ctc	cat	ctc	gac	ctg	tta	gtc

82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97
<i>ile</i>	<i>val</i>	<i>thr</i>	<i>ala</i>	<i>thr</i>	<i>gln</i>	<i>ser</i>	<i>asn</i>	<i>ile</i>	<i>cys</i>	<i>asp</i>	<i>glu</i>	<i>asp</i>	<i>ser</i>	<i>ala</i>	<i>thr</i>
ata	gtc	act	gcg	act	caa	agc	aac	att	tgc	gat	gag	gac	agc	gct	aca
tat	cag	tga	cgc	tga	gtt	tcg	ttg	taa	acg	cta	ctc	ctg	tcg	cga	tgt

100
<i>glu thr cys</i>
<i>gaa acc tgc</i>
<i>ctt tgg acg</i>

TABLE VIIPeptide and cDNA sequence of Domain L4 of TMDNA and Primary Amino Acid Sequence of T4 Fragment (TM aa residues 102-141)

102	103	104	109	110	111	112	113	114	115	116	117	118	119	120	121
<i>ser</i>	<i>thr</i>	<i>tyr</i>	<i>asp</i>	<i>arg</i>	<i>asn</i>	<i>lys</i>	<i>cys</i>	<i>tyr</i>	<i>thr</i>	<i>ala</i>	<i>val</i>	<i>val</i>	<i>pro</i>	<i>leu</i>	<i>val</i>
gc	acc	tac	gat	agg	aac	aaa	tgc	tac	acg	gcc	gtg	gtt	ccg	ctc	gtg
acg	tcg	tgg	atg	cta	tcc	ttg	ttt	acg	atg	tgc	cgg	cac	caa	ggc	gag

122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
<i>tyr</i>	<i>gly</i>	<i>gly</i>	<i>glu</i>	<i>thr</i>	<i>lys</i>	<i>met</i>	<i>val</i>	<i>glu</i>	<i>thr</i>	<i>ala</i>	<i>leu</i>	<i>thr</i>	<i>pro</i>	<i>asp</i>	<i>ala</i>	<i>cys</i>
tat	ggg	gga	gag	aca	aaa	atg	gtg	gaa	act	gcc	ctt	acg	ccc	gat	gca	tgc
ata	cca	cct	ctc	tgt	ttt	tac	cac	ctt	tga	cgg	gaa	tgc	ggg	cta	cgt	acg

139	140	141
<i>tyr</i>	<i>pro</i>	<i>asp</i>
<i>tac</i>	<i>cct</i>	<i>gac</i>
<i>atg</i>	<i>gga</i>	<i>ctg</i>
	<i>act</i>	<i>taa</i>

TABLE VIII

DNA Sequence and Primary Amino Acid Sequence of a Representative TM Core Element

9 10 11 12 13 14 15 16 17 18 19
asp gln lys cys lys cys ala arg ile thr ser
 gat cag aag tgc aag tgt gct cgt att act tct
 cta gtc ttc acg ttc aca cga gca taa tga aga

20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
arg ile ile arg ser ser glu asp pro asn glu asp ile val glu arg asn
 aga atc atc cgt agc tca gag gac cca aat gaa gat ata gtc gaa cgt aac
 tct tag tag gca tcg agt ctc ctg ggt tta ctt cta tat cag ctt gca ttg

37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53
ile arg ile ile val pro leu asn asn arg glu asn ile ser asp pro thr
 atc cgt atc atc gtc cca ctg aat aac cgg gag aat atc tca gat cct aca
 tag gca tag tag cag ggt gac tta ttg gcc ctc tta tag agt cta gga tgt

54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
ser pro leu arg thr arg phe val tyr his leu ser asp leu cys lys lys
 agt ccg ttg cgc aca cgc ttc gta tac cac ctg tca gat ctg tgt aag aag
 tca ggc aac gcg tgt gcg aag cat atg gtg gac agt cta gac aca ttc ttc

92 93 94 95 96 97 99 100 101
*asp glu asp ser ala thr glu thr cys OPA **Eco RI***
 gat gag gac agc gct aca gaa acc tgc tg
 cta ctc ctg tcg cga tgt ctt tgg acg act taa

TABLE IXDNA Sequence and Primary Amino Acid Structure of a Representative TM

9 10 11 12 13 14 15 16 17 18 19
asp gln lys cys lys cys ala arg ile thr ser
 gat cag aag tgc aag tgt gct cgt att act tct
 cta gtc ttc acg ttc aca cga gca taa tga aga

20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
arg ile ile arg ser ser glu asp pro asn glu asp ile val glu arg asn
 aga atc atc cgt agc tca gag gac cca aat gaa gat ata gtc gaa cgt aac
 tct tag tag gca tcg agt ctc ctg ggt tta ctt cta tat cag ctt gca ttg

37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53
ile arg ile ile val pro leu asn asn arg glu asn ile ser asp pro thr
 atc cgt atc atc gtc cca ctg aat aac cgg gag aat atc tca gat cct aca
 tag gca tag tag cag ggt gac tta ttg gcc ctc tta tag agt cta gga tgt

54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
ser pro leu arg thr arg phe val tyr his leu ser asp leu cys lys lys
 agt ccg ttg cgc aca cgc ttc gta tac cac ctg tca gat ctg tgt aag aag
 tca ggc aac gcg tgt gcg aag cat atg gtg gac agt cta gac aca ttc ttc

71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
cys asp pro thr glu val glu leu asp asn gln ile val thr ala thr gln
 tgt gat cca aca gag gta gag ctg gac aat cag ata gtc act gcg act caa
 aca cta ggt tgt ctc cat ctc gac ctg tta gtc tat cag tga cgc tga gtt

88 89 90 91 92 93 94 95 96 97 99 100 101 102
ser asn ile cys asp glu asp ser ala thr glu thr cys tyr OPA
 agc aac att tgc gat gag gac agc gct aca gaa acc tgc tac tga attc
 tcg ttg taa acg cta ctc ctg tcg cga tgt ctt tgg acg atg act

Table X
DNA and Primary Amino Acid Sequence of TpS2

101 102

cys ser asp asp asp asp lys ala gln thr glu thr cys thr val ala pro
gc gat gac gac gat aag gcc caa acg gag acc tgt act gtt gcg cct
act tcg cta ctg ctg cta ttc cgg gtt tgc ctc tgg aca tga caa cgc gga

arg glu arg gln asn cys gly phe pro gly val thr pro ser gln cys ala
cgt gaa cgg caa aac tgc gga ttc ccg gaa/gta aca ccc tct cag tgc gct
gca ctt gcc gtt ttg/acg cct aag ggc ctt cat tgt ggg aga gtc acg cga

asn lys gly cys cys phe asp asp thr val arg gly val pro trp cys phe
aat aaa ggc tgc tgt ttt gat gac acg gta cgg ggc gtt ccg tgg tgc ttc/
tta ttt ccg acg aca aaa cta ctg tgc cat gcc ccg/caa ggc acc acg aag

tyr pro asn thr ile asp val pro pro glu glu glu cys glu phe
tac ccc aat aca att gac gtt ccg cct gaa gaa gag tgc gag ccg taa g
atg ggg tta tgt taa ctg caa ggc gga ctt ctt ctc acg ctc ggc att cttaa

Example 2

Linkage of Imaging Agents to TM

[0117] This Example illustrates the preparation of dimeric IgA and TM linked to fluorescent and magnetic resonance imaging agents.

A. Dimeric IgA directly attached to imaging compounds

[0118] Native dimeric IgA isolated from biological sources as described above is reacted with the N-hydroxysuccinamide esters of (a) cyanine fluorochromes (Biological Detection Systems, Pittsburgh, PA) and (b) a manganese derivative of a sulfocyanine fluorochrome (MnPcS₄) prepared as described (Saini et al., *Magnetic Resonance Imaging* 13:985-990, 1995; Webber and Busch, *Inorg. Chem.* 4:469-471,

1965). The linkage reactions are performed as follows. Dimeric IgA is equilibrated with 0.1 M sodium bicarbonate, and pH adjusted to 8.7 using NaOH. The dIgA solution is then added directly to dyes either dried under vacuum onto the surface of the reaction vessel or previously dissolved in water. The NHS-diester react spontaneously with protein amino groups at neutral or basic pH. When commercially available kits (Biological Detection Systems, Pittsburgh, PA) are used according to the manufacturer's instructions, conjugates having 2-5 mol imaging compound per mol dIgA are obtained. To obtain higher or lower levels of conjugation, the ratio of the dye to protein is empirically adjusted to give a desired level of substitution. Typically, protein concentration is 20 mg/ml, while dye concentration varied from 1 to 10 mg/ml. Coupling is for 4 hours at room temperature or overnight at 4-6°C, with slow rotation of the mixture. Unreacted dye is blocked by addition of glycine to 0.1 M and adjustment of the pH to 8.7 followed by incubation at room temperature for 1-3 hours. Dye is removed and conjugates are equilibrated in PBS by three to four cycles of centrifugation and resuspension in Centricon-30 centrifugal ultrafilters (Amicon, Beverly, MA). If necessary, aggregates, typically less than 5% of the total dIgA, are removed by passage over Superose 12 (Pharmacia, Piscataway, NJ). The dye/protein ratio is estimated by taking the extinction coefficient of dIgA to be 1.5 A/mg protein/ml and assuming the extinction coefficients of the dye conjugates to be those of the free dyes. The compounds are referred to as dIgA-cyanine and dIgA-MnPcS₄.

[0119] The important properties of the dyes are summarized in Tables X and XI.

Table X
Optical Properties of Cyanine Dyes

Dye	Absorption		E280/Emax	Emission max., nm
	max. nm (PBS)	E at absorption max.		
Cy3.18	550	150,000	0.05	565
Cy5.18	652	250,000	0.05	667
Cy5.5.18	674	250,000	0.08	694

Table XI
Molar Relaxivities $1/T_1(\text{mMs})^{-1}$ of Paramagnetic Compounds

Compound	Relaxation rate
MnTPPS4	10.39*
MnCl ₂	9.32*
MriDTP A	6.93*
GdCl	14.67*
GDDTP A	5.05*
MnPcS ₄	10.10

* $1/T_1$ (mMs)⁻¹, in water at 10.7 MHz, 37°C.

B. TM directly attached to imaging compounds

[0120] TM is synthesized by phosphoramidite coupling as described above and contains no free sulfhydryl groups. The TM is purified from transgenic insect cells using procedures described above. The amino terminal as well as accessible lysines are available for attachment of NHS-imaging compound. When the commercially available kits (Biological Detection Systems, Pittsburgh, PA) are used according to the manufacturer's instructions, conjugates having 0.3-0.9 mol imaging compound per mol TM are obtained. These compounds are referred to as TM-cyanine and TM-MnPcS₄.

C. Dimeric IgA linked by a epithelial cell specific scissile peptide to imaging compounds

[0121] The polyimmunoglobulin receptor sequence from residues 585-600 (AIQDPRLFAEEKAVAD; SEQ ID NO:45), which is the substrate for an intracellular processing protease of epithelial cells, is synthesized by peptide coupling as described above. This peptide is reacted with the N-hydroxysuccinamide esters of cyanine imaging compounds (Biological Detection Systems, Pittsburgh, PA) as described above. The ratio of peptide to activated imaging compound is varied to optimize coupling reactions occurring at the amino terminal.

[0122] The peptide-imaging compound complex is further reacted with native dIgA purified from biological sources. The following solutions were prepared for

linking peptide-imaging compound to dIgA: *peptide-imaging compound stock solution* - 100 µg peptide-imaging compound, 0.2 mL water, 0.3 mL dimethylsulfoxide; *peptide-imaging compound/NHS* - 100 µL peptide-imaging compound stock solution, 0.4 mg N-hydroxysulfosuccinimide, 2 mL water; *EDC solution* - 2.46 mg 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide-HCl; *dIgA solution*: 5 mg per mL in water. Fifty µL of peptide-imaging compound-NHS was added to 50 µL of EDC solution followed by 50 µL of dIgA solution. The reaction was allowed to proceed at room temperature for 10 minutes to 2 hours and resulted in the conjugation of the peptide imaging compound via its carboxyl terminal to free amine groups of dimeric IgA. Reaction conditions were identified which enhance the derivatization and linkage at the terminal carboxyl group rather than the internal carboxyl of aspartate. The compounds are referred to as dIgA-pIgR-cyanine.

[0123] Control preparations are performed in identical fashion except the synthetic peptide linker had no cleavage site: VAVQSAGTPASGS (SEQ ID NO:93).

D. TM linked by an epithelial cell specific scissile peptide to imaging compounds

[0124] TM (extended) is synthesized by phosphoramidite coupling as described in C above and contains no free sulfhydryl groups. The TM is purified from transgenic insect cells using procedures described above. The amino terminal as well as accessible lysines are available for attachment of peptide-imaging compound.

[0125] The peptide-imaging compound complexes are prepared and further reacted with TM as described in C, above. The compounds are referred to as TM-pIgR-cyanine.

E. Dimeric IgA linked by a cancer cell specific scissile peptide to imaging compounds

[0126] The procedure described in C, above, is repeated except the pro-cathepsin sequence (KAHKVDMVQYT; SEQ ID NO:39) is used instead of the pIgR processing site. In this case, the peptide-imaging compound preparation contains one, two or three imaging compounds per peptide. The compounds are referred to as dIgA-cath-cyanine.

F. TM linked by a cancer cell specific scissile peptide to imaging compounds

[0127] The same procedure as described in D is repeated except the pro-cathepsin sequence (KAHKVDMVQYT; SEQ ID NO:39) is used instead of the pIgR processing site. In this case, the peptide-imaging compound preparation contains one, two or three imaging compounds per peptide. The compound is referred to as TM-cath-cyanine.

G. Fluorescent Compounds Targeted to the Endoplasmic Reticulum

[0128] *Fluorescent compound with a scissile linker attachment to synthetic TM.* The polyimmunoglobulin receptor sequence from residues 585-600 (AIQDPRLFAEEKAVAD) (SEQ ID NO:45), which is the substrate for an intracellular processing protease, is synthesized by peptide coupling as described above. This peptide is reacted with Texas Red hydrazide (Pierce) in dimethylformamide according to the instructions provided by the manufacturer. The ratio of peptide to hydrazide is varied to optimize coupling reactions occurring only at the carboxyl terminal. This population of reaction products is separated from other reaction products (*i.e.*, reactions at the internal aspartyl residue) by HPLC chromatography. The peptide-Texas Red complex is further reacted with SPDP (Pierce) according to the instructions provided by the manufacturer and is purified as above. The final reaction links the SPDP-peptide-Texas Red to the sulfhydryl groups of synthetic TM to form TM-peptide-TR. The TM structure used in these preparations is described in Table II as variation C. Control preparations are performed in identical fashion except the synthetic peptide linker has no cleavage site: VAVQSAGTPASGS (SEQ ID NO:93). The ER retention signal KDEL (SEQ ID NO:44) is synthesized as part of the TM core protein by phosphoramidite oligonucleotide coupling as described above and ligated into an insect expression vector to create pTM. The final compound is referred to as TM(kdel)-peptide-TR. Control preparations are performed in identical fashion except the synthetic peptide linker has no cleavage site: VAVQSAGTPASGS (SEQ ID NO:93).

[0129] *Fluorescent compound targeted to the nucleus.* Two nuclear targeting sequences CAAPKKKRKV (SEQ ID NO:84) and CAAKRPAAIKKAGQAKKKK

(SEQ ID NO:85) are synthesized by peptide coupling as described above. Each peptide is reacted with Texas Red hydrazide (Pierce Chemical Co.) in dimethylformamide according to the instructions provided by the manufacturer. The ratio of peptide to hydrazide is varied to optimize coupling reactions occurring only at the carboxyl terminal. This population of reaction products is separated from other reaction products by HPLC chromatography. The peptide-Texas Red complex is further reacted with MBPH (Pierce Chemical Co.) according to the instructions provided by the manufacturer and is purified as above. The final reaction links the MBPH-peptide-Texas Red to the carbohydrate groups of native TM isolated from biological sources as described above. Control preparations are performed in identical fashion except the synthetic peptide linker has no targeting function: VAVQSAGTPASGS (SEQ ID NO:93). The final compound is referred to as TM-peptide(nuc)-TR.

Example 3

Delivery of Imaging Agents

A. Delivery of Imaging Compounds to Cells *in vitro*

[0130] *Transcytosis of fluorescent imaging agents using dimeric IgA.* Confluent pIgR⁺ MDCK cell monolayer filters are incubated at the basolateral surface for twenty-four hours with dIgA attached directly to imaging agents (dIgA-cyanine) prepared as described above. Cells are then detached with trypsin (0.25% in 0.02% EDTA) (JRH Biosciences, Lenexa, KS), cytocentrifuged onto glass slides, and fixed with acetone. Fluorescence microscopy is used to detect the presence of the imaging agent in cells. Fluorescence in the upper chamber (apical) fluid was also measured. Cells incubated with the dIgA conjugates yield fluorescence only in the apical chamber and not inside the cells indicating the quantitative transcytosis of fluorescent compounds. In contrast, the free fluorescent compounds (unconjugated) partition inside the cells but no transcytosis to the apical surface is detected.

[0131] *Transcytosis of fluorescent imaging agents using TM.* The experiments as described above are performed using the TM conjugates (TM-cyanine). Cells

incubated with the TM conjugates also yield fluorescence only in the apical chamber and not inside the cells indicating the quantitative transcytosis of fluorescent compounds. The free fluorescent compounds (unconjugated) partition inside the cells but no transcytosis to the apical surface is detected.

[0132] *Delivery to epithelial cells of imaging agents linked to dimeric IgA via the pIgR peptide.* Confluent pIgR⁺ MDCK cell monolayer filters are incubated at the basolateral surface for twenty-four hours with dIgA-peptide conjugates (AIQDPRLFAEEKAVAD (SEQ ID NO:45); dIgA-pIgR-cyanine) prepared as described above. Cells are then detached with trypsin (0.25% in 0.02% EDTA) (JRH Biosciences, Lenexa, KS), cytocentrifuged onto glass slides, and fixed with acetone. Fluorescence microscopy is used to detect the presence of imaging compounds. Fluorescence in the upper chamber (apical) fluid was also measured. Cells incubated with dIgA-peptide conjugates yield a significant level of intracellular fluorescence. Apical fluorescence (transcytosis) is also apparent using scissile peptides. In contrast, the control conjugates, containing a non-scissile peptide, had no detectable intracellular fluorescence but significant levels of transcytosed fluorescence.

[0133] *Delivery to epithelial cells of imaging agents linked to TM via the pIgR peptide.* The above experiments are performed using the TM peptide conjugates (TM-pIgR-cyanine). Cells incubated with TM-peptide conjugates yield a significant level of intracellular fluorescence. Apical fluorescence (transcytosis) is also apparent using scissile peptides. In contrast, the control conjugates, containing a non-scissile peptide, had no detectable intracellular fluorescence but significant levels of transcytosed fluorescence.

[0134] *Delivery of a fluorescent compound targeted for retention in the endoplasmic reticulum.* Confluent pIgR⁺ MDCK cell monolayer filters are incubated at the basolateral surface for twenty-four hours with TM(kdel)-peptide-TR prepared as described above. Cells are then detached with trypsin (0.25% in 0.02% EDTA) (JRH Biosciences, Lenexa, KS), cytocentrifuged onto glass slides, and fixed with acetone. Fluorescence microscopy (580 nm excitation, 604 nm emission wavelengths) is used to detect the presence of Texas Red. Cells incubated with TM(kdel)-peptide-TR yielded a detectable level of fluorescence whereas the control construct, containing a non-

scissile peptide, had no detectable fluorescence. Fluorescence is further localized to intracellular structures consistent with endomembrane organelles.

[0135] *Delivery of a fluorescent compound to nuclei.* MDCK cells stably transfected with cDNA encoding the rabbit pIgR are cultured on nitrocellulose filters in microwell chambers (Millicell; Millipore, Bedford, MA.). Confluent pIgR⁺ MDCK cell monolayer filters are incubated with TM-peptide(nuc)-TR containing nuclear targeting sequences or the control TM-peptide-TR with no sequences, via the lower compartment. Twenty-four hours after the addition of TM, cells are detached with trypsin (0.25% in 0.02% EDTA) (JRH Biosciences, Lenexa, KS), cytocentrifuged onto glass slides, and fixed with acetone. Immunofluorescence is used to detect Texas Red.

[0136] TM-peptide(nuc)-TR localizes nuclei as documented by immunofluorescence. These observations indicate that during epithelial transcytosis, specific TM-peptide(nuc)-TR antibody can interact with cytoplasmic or endomembrane receptors and undergo transport to the nucleus. In contrast, infected monolayers treated with TM-peptide-TR containing no nuclear targeting signal do not demonstrate nuclear fluorescence localization. These studies document that MDCK cells transport specific TM-peptide(nuc)-TR containing nuclear targeting sequences to the nucleus, but do not transport TM-peptide-TR without these sequences.

[0137] *Delivery to cancer cells of imaging agents linked to dimeric IgA via the cathepsin peptide.* Confluent pIgR⁺ HT-29 colon carcinoma cell monolayer filters are incubated at the basolateral surface for twenty-four hours with dIgA-peptide conjugates (KAHKVDMVQYT peptide (SEQ ID NO:39); dIgA-cath-cyanine) prepared as described above. Cells are then detached with trypsin (0.25% in 0.02% EDTA) (JRH Biosciences, Lenexa, KS), cytocentrifuged onto glass slides, and fixed with acetone. Fluorescence microscopy is used to detect the presence of imaging compounds. Fluorescence in the upper chamber (apical) fluid was also measured. Cells incubated with dIgA-peptide conjugates yield a significant level of intracellular fluorescence. Apical fluorescence (transcytosis) is also apparent using scissile peptides. In contrast, the control conjugates, containing a non-scissile peptide, had no detectable intracellular fluorescence but significant levels of transcytosed fluorescence.

[0138] *Delivery to cancer cells of imaging agents linked to TM via the cathepsin peptide.* The same experiments are performed using the TM peptide conjugates (TM-cath-cyanine). Cells incubated with TM-peptide conjugates yield a significant level of intracellular fluorescence. Apical fluorescence (transcytosis) is also apparent using scissile peptides. In contrast, the control conjugates, containing a non-scissile peptide, had no detectable intracellular fluorescence but significant levels of transcytosed fluorescence.

B. Delivery of Imaging Compounds to Epithelial Cells *in vivo*

[0139] *Fluorescence imaging with dimeric IgA directly attached to cyanine conjugates.* Mice are tail-vein injected using 10-100 μ g dIgA-cyanine. Immediately after injection, and typically at 12 hour intervals thereafter, mice are anesthetized using sodium pentobarbital, 65 mg/kg. Mice are imaged using one of three camera systems: a Photometrics C200 12-bit cooled CCD (Photometrics, Tucson, AZ), a Hamamatsu C2400 8-bit CCD with microchannel-plate enhancer, or a Hamamatsu C4480 cooled 12-bit CCD (Hamamatsu Photonics, Bridgewater, NJ). Illumination is provided by 35-W fiber-optic illuminators (Model 190, Dolan-Jenner, Woburn, MA) with filters attached to the fiber output, a Storz 484C halogen illuminator equipped with a filter adapter and a 495FL light conducting cable (Karl Storz, Culver City, CA), or handheld diode lasers, having maximum output at 635 nm (for Cy5) or 672 nm (for Cy5.5). All illuminators performed satisfactorily, although some background emission from the exciting light is visible at high intensification or after long exposure, even when lasers are used.

[0140] Three different lens systems are used: a Nikon 50 mm f1.8 AF Nikkor for full-sized views of the animals, a Storz 27015A Hopkins Telescope to investigate endoscopic viewing, and an Olympus SZH-ILLD dissecting microscope equipped with a camera port for close-UPS. Interference filters are from Omega Optical (Brattleboro, VT). The filter combinations used are:

Fluorochrome	Excitation filter	Emission filter
Cy3	535DF20	59ODF30
Cy5	61ODF20	67ODF40
Cy5.5	67ODF20	700EFLP

Free dye is rapidly excreted in the urine, with only kidneys and bladder showing any significant fluorescence. Most of the dye is excreted within 4 hours, and there is no detectable retention at 24-48 hours. The pattern of conjugated dye retention is quite different. Immediately after injection, blood vessels were very bright and readily resolved through the skin. Liver, kidneys, spleen and bladder were next brightest, and could also be seen through the animal's skin. After 4-6 hours, while fluorescence of major organs persisted, the brightest normal organ in the animal is the gallbladder. This high concentration of fluorescence is presumably caused by uptake and catabolism of antibody by the liver, followed by deposition of the catabolites in the gallbladder. After 2 days, the brightest normal organ in the mouse is the intestine, which is particularly clear when viewed from the animal's ventral aspect. The label persists, remaining clearly detectable 5 days after injection; at the same dose and at ten-fold higher dose than the conjugate, free dye is not retained by the intestine. Microscopic examination showed that fluorescence is concentrated in the lamina propria.

[0141] *Fluorescence imaging with TM directly attached to cyanine conjugates.* The procedures described above for dimeric IgA are used. Animals are tail vein injected as described above with TM-cyanine. The results are similar to those obtained using dimeric IgA. Immediately after injection, blood vessels were very bright and readily resolved through the skin. Liver, kidneys, spleen, lung and bladder were bright, and could also be seen through the animal's skin. After 2 hours, while fluorescence of major organs persisted, the brightest normal organ in the animal is the gallbladder. After 1 day, the brightest normal organ in the mouse is the intestine. Maximal distribution to normal tissue is observed at 24 hours post injection rather than at 48 hours. This result may be due to the relatively small size of the TM conjugate compared to the dIgA conjugate indicating a more rapid transendothelial tissue distribution.

[0142] *Fluorescence imaging with dimeric IgA attached to cyanine conjugates via the pIgR peptide.* The procedures described above are used. Animals are tail vein injected as described above with dIgA-pIgR-cyanine. The results are similar to those obtained using dimeric IgA conjugated directly to fluorochromes. Immediately after injection, blood vessels are very bright and readily resolved through the skin. Liver, kidneys, spleen, lung and bladder are bright, and can also be seen through the animal's skin. After 4-6 hours, while fluorescence of major organs persisted, the brightest normal organ in the animal is the gallbladder. After 2 days, the brightest normal organ in the mouse is the intestine however with the pIgR peptide linker the fluorescence intensity is far less diffuse and appears to be confined to a discrete population of intestinal cells. This is indicative of fluorochrome release during transcytosis with subsequent intracellular retention of fluorochrome in epithelial cells.

[0143] *Fluorescence imaging with TM attached to cyanine conjugates via the pIgR peptide.* The procedures described above are used. Animals are tail vein injected as described above with TM-pIgR-cyanine. The results are similar to those obtained using TM conjugated directly to fluorochromes. Immediately after injection, blood vessels are very bright and readily resolved through the skin. Liver, kidneys, spleen, lung and bladder are bright, and can also be seen through the animal's skin. After 2-4 hours, while fluorescence of major organs persisted, the brightest normal organ in the animal is the gallbladder. After 1 day, the brightest normal organ in the mouse is the intestine however with the pIgR peptide linker the fluorescence intensity is far less diffuse and appears to be confined to a discrete population of intestinal cells. This is indicative of fluorochrome release during transcytosis with subsequent intracellular retention of fluorochrome in epithelial cells. Maximal distribution to normal tissue is observed at 24 hours post injection rather than at 48 hours. This result may be due to the relatively small size of the TM conjugate compared to the dIgA conjugate indicating a more rapid transendothelial tissue distribution.

[0144] *Fluorescence imaging with dimeric IgA attached to cyanine conjugates via the cathepsin peptide.* The human HT-29 colon carcinoma was purchased from American Type Culture Collection. Tumors are grown in nude (BALB/c background) mice; the tumor was also grown in BALB/c mice. Typically 10^6 cells are inoculated s.c.

or i.m. Tumors are selected because these are well-studied systems containing pIgR receptors, and a comparison with previous results obtained using, radioactive or therapeutic drug-antibody conjugates was possible.

[0145] Immediately after injection with dIgA-cath-cyanine (10-100 μ g), blood vessels were very bright and readily resolved through the skin. Liver, kidneys, spleen and bladder were next brightest, and could also be seen through the animal's skin. After 4-6 hours, while fluorescence of major organs persisted, the brightest normal organ in the animal is the gallbladder. After 2 days, the brightest normal organ in the mouse is the intestine, which is particularly clear when viewed from the animal's ventral aspect.

[0146] Tumors are initially less fluorescent than the surrounding tissues, as expected. By 2 hours after injection, the situation is reversed. Visibility and contrast are best at 24-48 hours; tumors could be imaged through millimeter thicknesses of skin and muscle. Considerable structure could be imaged through the skin. Visibility of the tumors did not improve further after 48 hours. Small tumors are readily imaged through the skin. Non-specific conjugates labeled using the cyanine fluorochromes Cy3 or Cy5 (Biological Detection Systems, Pittsburgh, PA) showed no targeting to the tumors.

[0147] Cy5-dIgA conjugate is extremely persistent in tumors. One mouse was imaged for 5 days after dye injection using Cy5-dIgA and euthanized, after which its tumor was removed and frozen thin sections prepared.

[0148] To demonstrate that Cy5 conjugation by itself causes no tumor localization of dIgA, the non-specific plasmacytoma immunoglobulin MOPC-104E was conjugated to Cy5, while dIgA was conjugated to Cy5.5. The CY5.5-specific dIgA conjugate was retained by the tumor, but not the non-specific Cy5 antibody conjugate.

[0149] *Fluorescence imaging with TM attached to cyanine conjugates via the cathepsin peptide.* The procedures described above are used. Immediately after injection with TM-cath-cyanine (10-100 μ g), blood vessels were very bright and readily resolved through the skin. Liver, kidneys, spleen, lung and bladder were bright, and could also be seen through the animal's skin. After 2 hours, while fluorescence of major organs persisted, the brightest normal organ in the animal is the gallbladder. After 1 day, the brightest normal organ in the mouse is the intestine.

[0150] Tumors are initially less fluorescent than the surrounding tissues, as expected. By 1 hour after injection, the situation was reversed. Visibility and contrast are best at 12-24 hours; tumors could be imaged through millimeter thicknesses of skin and muscle. Considerable structure could be imaged through the skin. Visibility of the tumors did not improve further after 48 hours. Small tumors are readily imaged through the skin. Non-specific conjugates labeled using Cy3 or Cy5 showed no targeting to the tumors. Maximal distribution to tumors is observed at 24 hours post injection rather than at 48 hours. This result may be due to the relatively small size of the TM conjugate compared to the dIgA conjugate indicating a more rapid transendothelial tissue distribution.

[0151] *MRI imaging with dimeric IgA attached to cyanine conjugates via the cathepsin peptide.* C3HJax mice (4-6 weeks) are implanted with 2.6×10^6 tumor cells (human mammary carcinoma) subcutaneously in the region of the hind limb. A solid tumor of approximately 1 cm in diameter is apparent at the time of administration of the dye (metal complex). A calculated dose of dIgA-MnPCS4 (96 mg/kg body weight) solubilised in sterile water at pH 6.2, is injected into the lateral vein of the tail of the mice for biodistribution studies and MR imaging. For toxicity experiments, the C3H Jacks mice in a group of 10 animals each are taken, MnPCS4 dye is injected (IP) at a varying concentration of from 100 to 650 mg/kg of body weight. All the animals are put under observation for 30 days post injection.

[0152] For *in vivo* MR imaging, each animal is anaesthetized by subcutaneous injection of 0.1 ml (20 mg/kg) of ketamine and 0.02 ml (4 mg/kg) of diazepam sodium. The dose is repeated before each set of imaging experiments during the study. MR images are taken before and then at 1 hour and 24 hours after intravenous administration of the dye. The animal is positioned in a rat trap and placed in a thermostat enclosure during the study to avoid hypothermia in the imaging room. MR images are taken in a 1.5 Tesla superconducting clinical MRI system (MAGNETOM, Siemens, Germany) using 15 cm surface RF coil in the prone position. Continuous 4-mm slices are taken in the coronal plane with T1 weighted spin echo sequence (TE 17/TR 500 ms) with 2 averages using 256 x 256 matrix size. This provided an intrinsic resolution of 0.7 mm in the image plane. Care is taken to reproduce the slice position in

serial studies by fixing the light localizer to coincide with predefined external markers over the animal and the surface coil. Copper nitrate solution (0.046 mol) in a glass tube placed adjacent to the animal during the imaging experiment provided a reference standard of image incalculated by drawing a region of interest (ROI) on the tumor, normal muscle in the contralateral hind limb, liver, spleen, and kidney are recorded in each set of images before and at various time intervals after administration of the dye for evaluation. Relative change in the average image intensity and image intensity normalized with the standard at various time intervals over the preinjection value provided information regarding relative concentration and transit of the injected dye.

[0153] For tumor imaging, all the animals ($n = 5$) tolerated well the intravenous dose of 96 mg/kg. Blueish discoloration of the skin is evident immediately following intravenous administration of the dye, which clears off with time during the next 3 to 5 days. Visual difference in image intensity in the tumor, muscle, liver, and kidney between the control and treated animals at various time intervals are quantitated using the mean intensity value measured over identical regions of interest (ROI) and normalized to a corresponding value of the working standard. A significant increase in the intensity in the tumor is observed over the control value up to 48 hours post injection. Tumor-to-muscle ratio of normalized signal intensity is maximum at 48 hours compared to the control value. Maximum image intensity in the liver is found at 48 hours. Maximal image intensity at 48 hours indicates substantial uptake and retention of dIgA-MnPCS4 in the normal liver tissue. Kidneys showed the maximum value of percent increase in the signal intensity at 6 hours followed by a gradual decrease over 48 hours. Serial MR images of the mice before and after 1 and 24 hours postinjection show diffuse enhancement of the tumor in the right hind limb at 1 hour, which further increases with improved tumor-to-muscle background at 24 hours. In the case of large tumors associated with areas of necrosis, enhancement is confined to the solid areas of the tumor leaving the necrotic areas unenhanced and giving the tumor a mottled appearance. However, there is gradual filling in of the unenhanced zones with over the course of three days.

[0154] *MRI imaging with TM attached to cyanine conjugates via the cathepsin peptide.* Results substantially similar to dIgA conjugates are observed using TM

conjugates (TM-MnPcS4); however maximal distribution to tumor tissue is observed at 10-20 hours post injection rather than at 48 hours. This result may be due to the relatively small size of the TM conjugate compared to the dIgA conjugate indicating a more rapid transendothelial tissue distribution.

[0155] From the foregoing, it will be appreciated that, although specific embodiments of the invention have been described herein for the purpose of illustration, various modifications may be made without deviating from the spirit and scope of the invention.

Summary of Sequence Listing

SEQ ID NO:1 is amino acid sequence of human J chain
 SEQ ID NO:2 is amino acid sequence of mouse J chain
 SEQ ID NO:3 is amino acid sequence of rabbit J chain
 SEQ ID NO:4 is amino acid sequence of bovine J chain
 SEQ ID NO:5 is amino acid sequence of bull frog J chain
 SEQ ID NO:6 is amino acid sequence of earth worm J chain
 SEQ ID NO:7 is nucleotide sequence of "full length" TM cDNA (Table II)
 SEQ ID NO:8 is nucleotide sequence of Core TM cDNA (Table VIII)
 SEQ ID NO:9 is nucleotide sequence of C2 fragment (Table IV)
 SEQ ID NO:10 is nucleotide sequence of D1.1 fragment (Table V)
 SEQ ID NO:11 is nucleotide sequence of L3D fragment (Table VI)
 SEQ ID NO:12 is nucleotide sequence of T4 fragment (Table VII)
 SEQ ID NO:13 is nucleotide sequence of Core TM cDNA using L3 (Table IX)
 SEQ ID NO:14 is nucleotide sequence of L3 fragment (Table VI.A)
 SEQ ID NO:15 is nucleotide sequence of D1 fragment (Table V.A)
 SEQ ID NO:16 is nucleotide sequence of TpS2 (Table X)
 SEQ ID NO:17 is amino acid sequence of "full length" TM cDNA (Table II)
 SEQ ID NO:18 is amino acid sequence of Core TM cDNA (Table VII)
 SEQ ID NO:19 is amino acid sequence of C2 fragment (Table IV)
 SEQ ID NO:20 is amino acid sequence of D1.1 fragment (Table V)
 SEQ ID NO:21 is amino acid sequence of L3D fragment (Table VI)
 SEQ ID NO:22 is amino acid sequence of T4 fragment (Table VII)
 SEQ ID NO:23 is amino acid sequence of Core TM cDNA using L3 (Table IX)
 SEQ ID NO:24 is amino acid sequence of L3 fragment (Table VI.A)
 SEQ ID NO:25 is amino acid sequence of D1 fragment (Table V.A)

SEQ ID NO:26 is amino acid sequence of TpS2 (Table X)

SEQ ID NO:27 is complementary nucleotide sequence of “full length” TM cDNA
(Table II)

SEQ ID NO:28 is complementary nucleotide sequence of Core TM cDNA (Table VIII)

SEQ ID NO:29 is complementary nucleotide sequence of C2 fragment (Table IV)

SEQ ID NO:30 is complementary nucleotide sequence of D1.1 fragment (Table V)

SEQ ID NO:31 is complementary nucleotide sequence of L3D fragment (Table VI)

SEQ ID NO:32 is complementary nucleotide sequence of T4 fragment (Table VII)

SEQ ID NO:33 is complementary nucleotide sequence of Core TM cDNA using L3
(Table IX)

SEQ ID NO:34 is complementary nucleotide sequence of L3 fragment (Table VI.A)

SEQ ID NO:35 is complementary nucleotide sequence of D1 fragment (Table V.A)

SEQ ID NO:36 is complementary nucleotide sequence of TpS2 (Table X)

SEQ ID NO:37 is Domain 1, 13 amino acid peptide with substantial β -sheet character

SEQ ID NO:38 is peptide recognized by the tobacco etch virus protease Nia

SEQ ID NO:39 is amino acid residues from pro-cathepsin E

SEQ ID NO:40 is linker from procathepsin

SEQ ID NO:41 is linker from polyimmunoglobulin receptor

SEQ ID NO:42 is nucleotide sequence of secretion signal from pMelBac

SEQ ID NO:43 is amino acid sequence of secretion signal from pMelBac

SEQ ID NO:44 is endomembrane retention signal

SEQ ID NO:45 is residues 585-600 of polyimmunoglobulin receptor

SEQ ID NO:46 is Oligonucleotide 1

SEQ ID NO:47 is Oligonucleotide 2

SEQ ID NO:48 is Oligonucleotide 1.1

SEQ ID NO:49 is Oligonucleotide 1.2

SEQ ID NO:50 is Oligonucleotide 1.2ser

SEQ ID NO:51 is Oligonucleotide 2.2ser

SEQ ID NO:52 is Oligonucleotide 1.2val

SEQ ID NO:53 is Oligonucleotide 2.2val

SEQ ID NO:54 is Oligonucleotide 3

SEQ ID NO:55 is Oligonucleotide 4

SEQ ID NO:56 is Oligonucleotide 5

SEQ ID NO:57 is Oligonucleotide 5.1dg

SEQ ID NO:58 is Oligonucleotide 6

SEQ ID NO:59 is Oligonucleotide 6.1dg
SEQ ID NO:60 is Oligonucleotide 7
SEQ ID NO:61 is Oligonucleotide 8
SEQ ID NO:62 is Oligonucleotide 9
SEQ ID NO:63 is Oligonucleotide 9L3Δ
SEQ ID NO:64 is Oligonucleotide 10L3Δ
SEQ ID NO:65 is Oligonucleotide 9L3ΔKDEL
SEQ ID NO:66 is Oligonucleotide 10L3ΔKDEL
SEQ ID NO:67 is Oligonucleotide 9.2Δ3
SEQ ID NO:68 is Oligonucleotide 10.2Δ3
SEQ ID NO:69 is Oligonucleotide 9.3Δ3/ser68
SEQ ID NO:70 is Oligonucleotide 10.3Δ3/ser68
SEQ ID NO:71 is Oligonucleotide 9.3Δ3/val68
SEQ ID NO:72 is Oligonucleotide 10.3Δ3/val68
SEQ ID NO:73 is Oligonucleotide 10
SEQ ID NO:74 is Oligonucleotide 11
SEQ ID NO:75 is Oligonucleotide 12
SEQ ID NO:76 is Oligonucleotide 13
SEQ ID NO:77 is Oligonucleotide 14
SEQ ID NO:78 is Oligonucleotide 15
SEQ ID NO:79 is Oligonucleotide 16
SEQ ID NO:80 is Oligonucleotide 15KDEL
SEQ ID NO:81 is Oligonucleotide 16KDEL
SEQ ID NO:82 is Oligonucleotide P1
SEQ ID NO:83 is Oligonucleotide P2
SEQ ID NO:84 is nuclear targeting sequence 1
SEQ ID NO:85 is nuclear target sequence 2
SEQ ID NO:86 is HDEL linker sequence for intracellular targeting
SEQ ID NO:87 is Oligonucleotide Tp1
SEQ ID NO:88 is Oligonucleotide Tp2
SEQ ID NO:89 is Oligonucleotide Tp3
SEQ ID NO:90 is Oligonucleotide Tp4
SEQ ID NO:91 is Oligonucleotide Tp5
SEQ ID NO:92 is Oligonucleotide Tp6
SEQ ID NO:93 is synthetic peptide linker